Fermilab

Tevatron Operations Status

Accelerator Advisory Committee
February 4-6, 2003

Mike Martens

Introduction

Parameter	Current Status	FY03 Goal	Run II Goal	
Typical Luminosity	3.2e31	6.6e31	33e31	$cm^{-2}sec^{-1}$
Integrated Luminosity	6.0	12.0	70.0	pb^{-1}/week
Protons/bunch	170e9	240e9	270e9	
Antiprotons/bunch	22e9	31e9	135e9	

Higher intensity ⇒ Fundamental physics limitations

- Beam-Beam Effects
- Instabilities
- Beam Halo and Lifetimes

Understanding/Solving these issues requires …

- Stable Tevatron Lattice
- Diagnostics
- Study Time

Contents

- Luminosity since June 2002
- Major topics being addressed:
  - Tevatron Lattice (tunes/coupling/orbits)
  - Beam-Beam Effects
  - Instabilities and Dampers
  - Diagnostics
  - January 2003 shutdown
  - Goals for this year
- Summary

Luminosity Since June 2002

Slides related to luminosity performance

- Luminosity formula
- Goals and current performance
- Peak luminosity plot
- Improvement in luminosity by factor of 1.9
- Beam intensities
- Transfer efficiencies
- Beam emittances
- Store reliability

Luminosity Formula

$$L = \frac{10^{-6} f\ B\ N_p N_{\bar{p}} \left(6\beta_r\gamma_r\right)}{2\pi\beta^*\left(\varepsilon_p + \varepsilon_{\bar{p}}\right)} H\left(\sigma_l / \beta^*\right)$$ **(10^{31} cm^{-2} sec^{-1})**

f = revolution frequency = 47.7 KHz

B = # bunches = 36

$\beta_r\gamma_r$ = relativistic beta x gamma = 1045

β^* = beta function at IR = 35 cm

H = hourglass factor = .60 - .70

N_p , N_{pbar} = bunch intensities (E9)

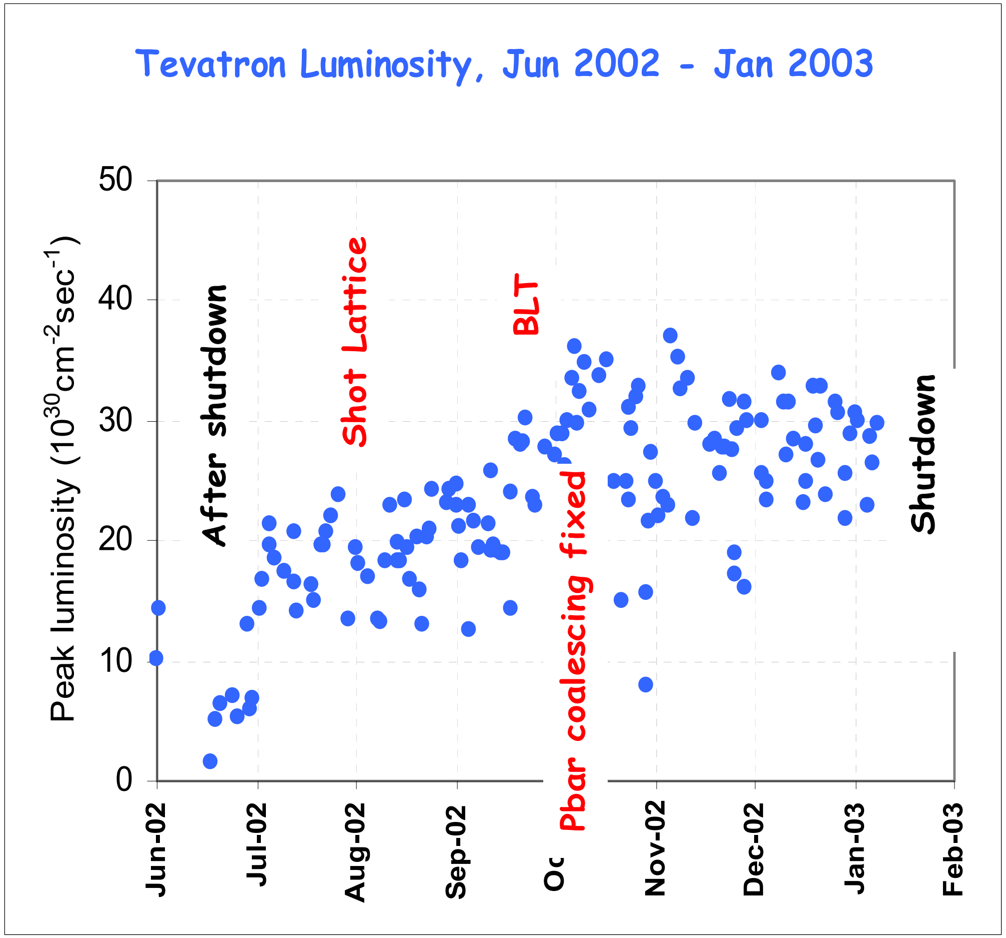
ε_p , ε_{pbar} = transverse emittances (π-mm-mrad)

σ_l = bunch length (cm)

Goals and Current Performance

Parameter	Current Performance	FY03 Goal	Run II Goal	
Typical Luminosity	3.2e31	6.6e31	33e31	$cm^{-2}sec^{-1}$
Integrated Luminosity	6.0	12.0	70.0	pb^{-1}/week
Protons/bunch	170e9	240e9	270e9	
Antiprotons/bunch	22e9	31e9	135e9	
Proton emittance (95%, norm)	20	20	20	pmm-mr
Pbar emittance (95%, norm)	18	15	14	pmm-mr
Bunch length rms (prot, pbar)	0.6	0.54	0.54	meter
Peak Pbar Production Rate	11.5e10	18e10	45e10	/hr
Pbar: AA -> Low β efficiency	0.60-0.75	0.8	0.85	
Pbar: Inj. -> Low β efficiency	~ 0.75			
Number of bunches	36x36	36x36	36x36	
Beta @ IP	0.35	0.35*	0.35	meter
Beam Energy	980	980	980	GeV

Tevatron Since June 2002



- 151 HEP stores
- 160 pb^{-1} to each detector
- Increase in luminosity from 20e30 to 36.9e30
- Run I record of 25.0e30 broken on 7/26/2002
- Run II record of 36.9e30 set on 11/8/2002
- Not much improvement in luminosity since November 2002

… Increases tend to follow significant improvements, e.g., →

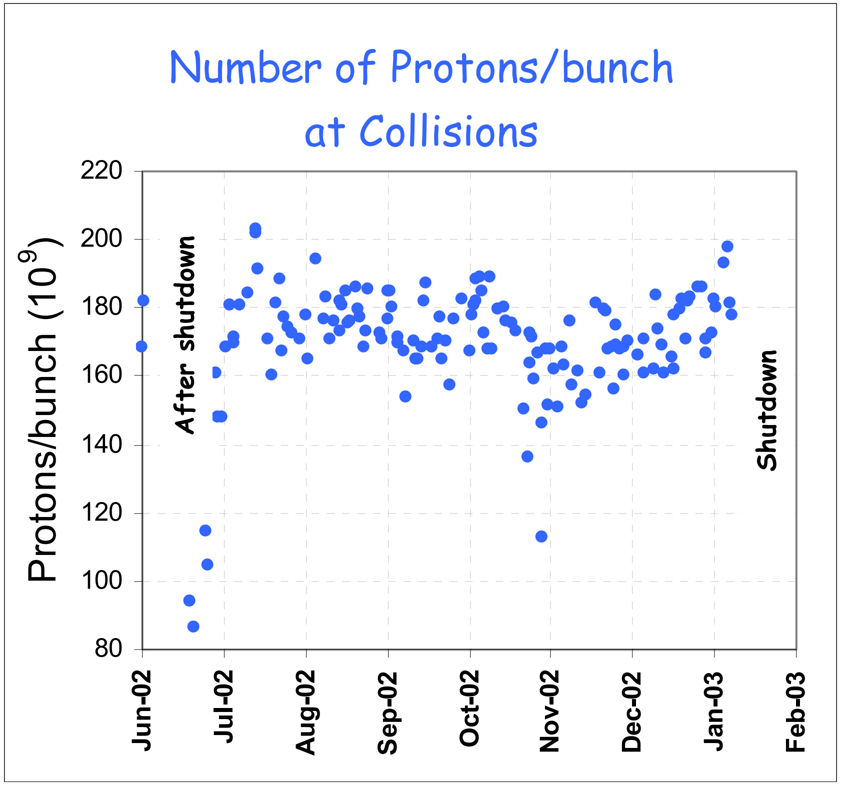
Reasons for $\mathcal{L}$-progress Since Jun'02

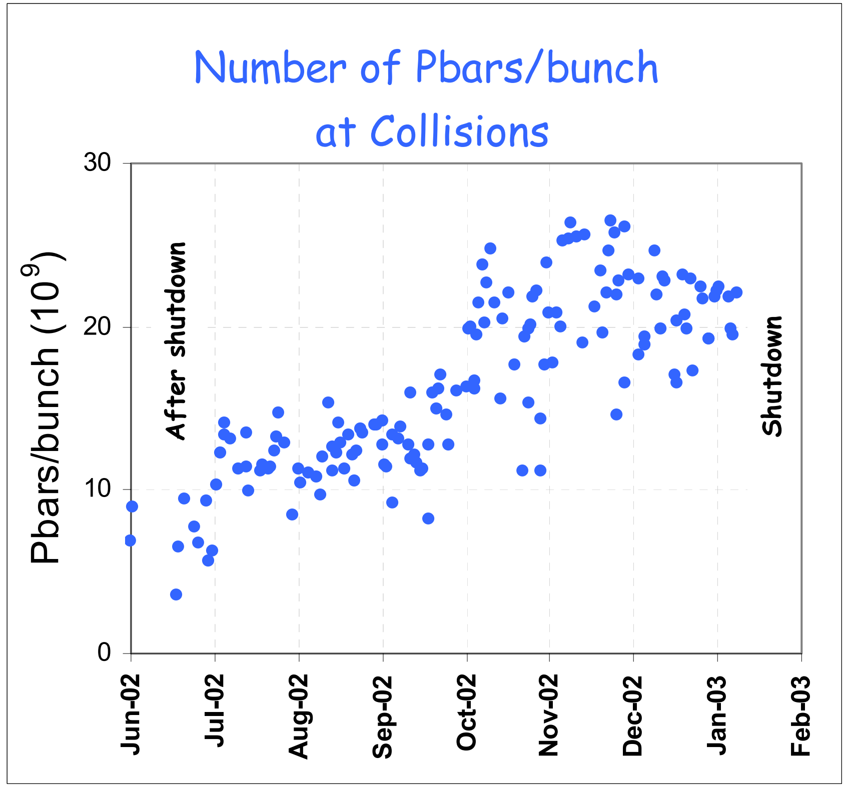
• "Shot lattice"	*AA*	x 1.40
• Pbar emittance at injection	Tev/Lines	x 1.20
• Pbar coalescing improvement	MI	x 1.15
	total	x 1.9

....plus additional improvements in the Tevatron:

- Tunes/coupling/chromaticities at 150/ramp/LB
- Orbit smoothing
- Longitudinal dampers to stop σ_s blowup
- Transverse dampers improves 150 Gev lifetime
- Separator scans
- F11 vacuum

Beam Intensities in 2002





<u>Number of protons</u>

Mostly steady

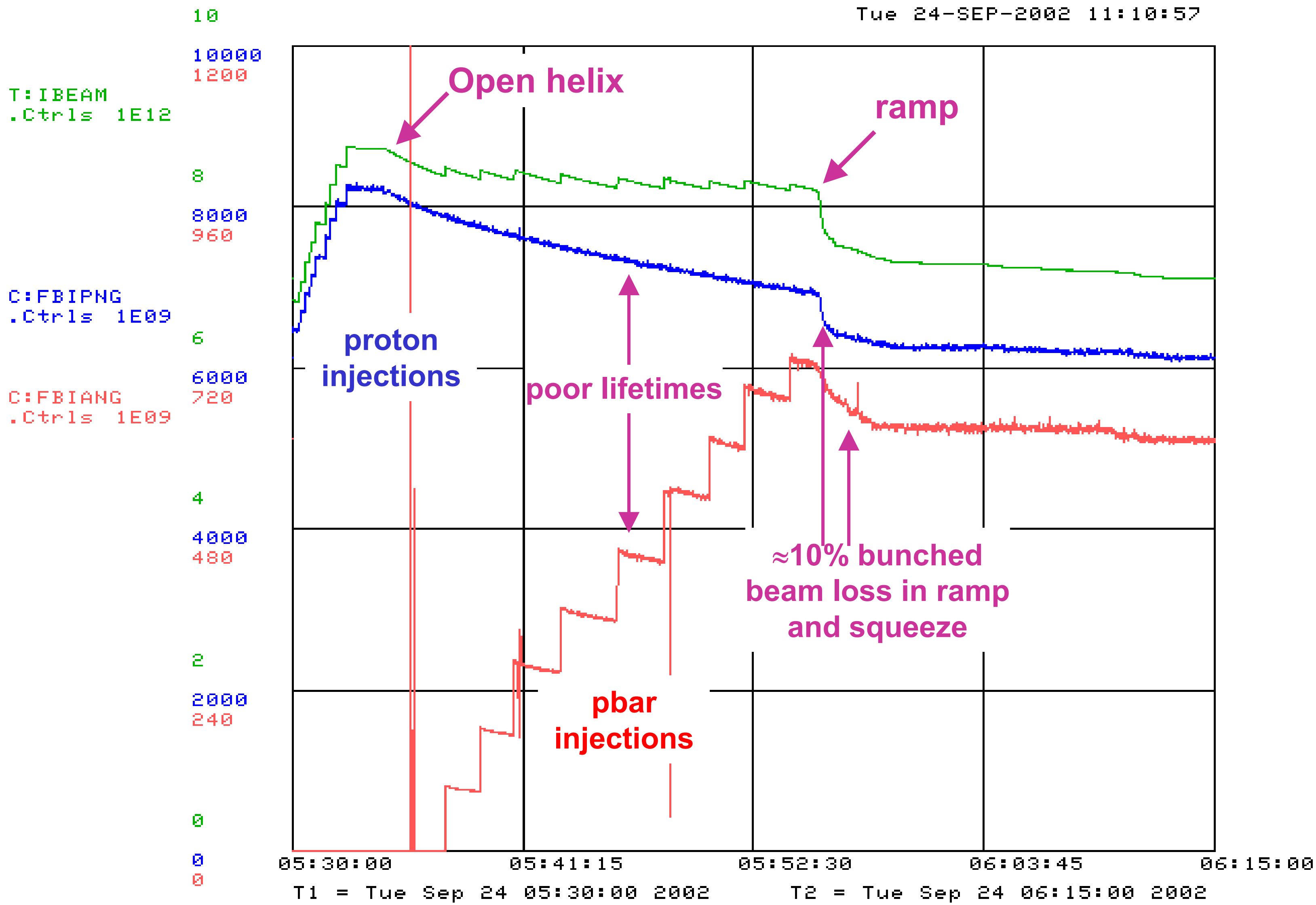
in the 160 e9 ⇒ 200e9 range

<u>Number of antiprotons</u>

Increase factor of 2.5 Oct ⇒ March

from 9e9 ⇒ 22e9 per bunch

Tevatron Efficiencies



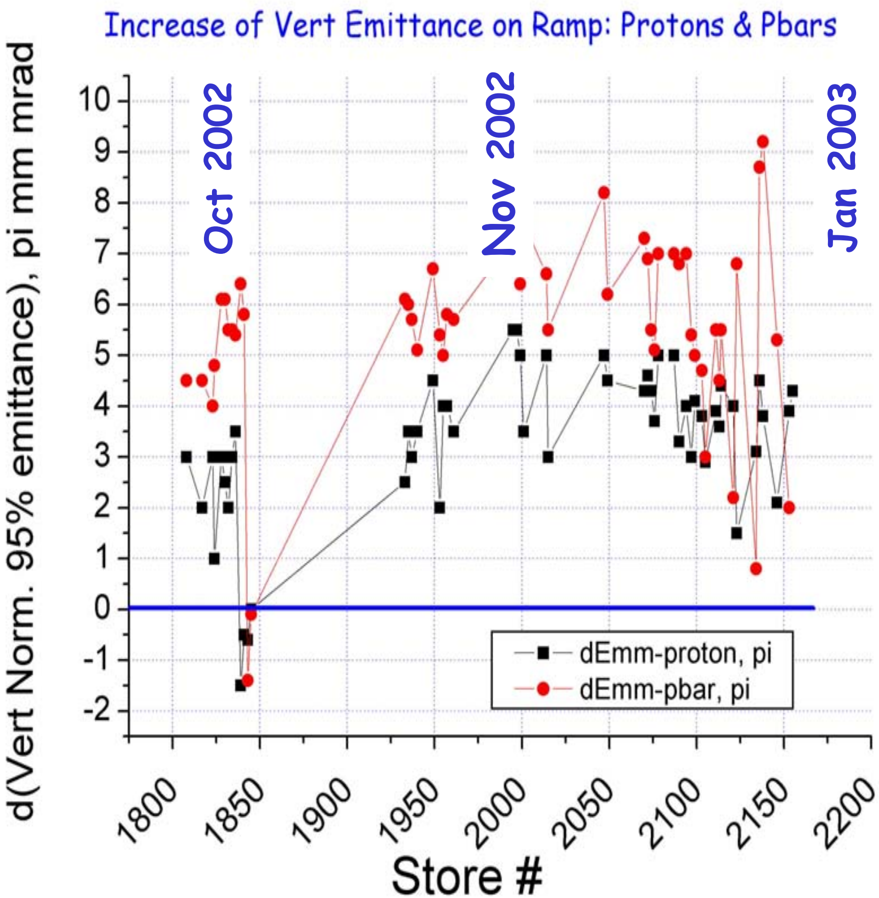
Tevatron Emittance

General comments on emittance blow-up from Flying Wire measurement**
(95%, normalized emittances):

- < 1π - 2π at proton injection
- ~ 5π - 6π at pbar injection
- < (negative) 2π - 3π protons at 150 (scraping)
- ~ (negative) 0π -3π pbars at 150 (scraping)
- 4π -7π blowup on ramp (prots and pbars)
- occasional instability, 5π – 50π, at 980 Gev
- scallop emittances for pbars (+20π)

** There remains uncertainty of FW emittance measurements. (See later slides)

Tevatron Emittance on the Ramp



**Note: Possible that this is a FW effect. (See later slides.)

Emittance blow-up on the ramp**

- In both p and pbars
- Same for coalesced and uncoalesced
- About 5-7π in vertical (not sure for horizontal)

- Worse after Nov.1
- WHY?
- Not due to dampers
- Tune adjustments did not help

Tevatron Reliability

- 151 stores from 6/1/2002 to 1/11/2003
- 99 (65%) ended intentionally
- 52 stores ended with failure
  - (10) Quench Protection Monitor (QPM) system
  - (7) Power glitch
  - (6) Cryogenics system
  - (4) Kicker pre-fire
  - (4) Quench on abort
  - (3) RF
  - (3) Tevatron Power Supply
  - (2) Power supply
  - (2) Kicker
  - (2) Controls
  - (1) Studies
  - (1) Collimator
  - (1) Safety system
  - **And 1 Earthquake in Alaska**

See P. Czarapata Talk
on Reliability Improvements
- QPM VFCs
- Cryogenics
- Kicker pre-fire

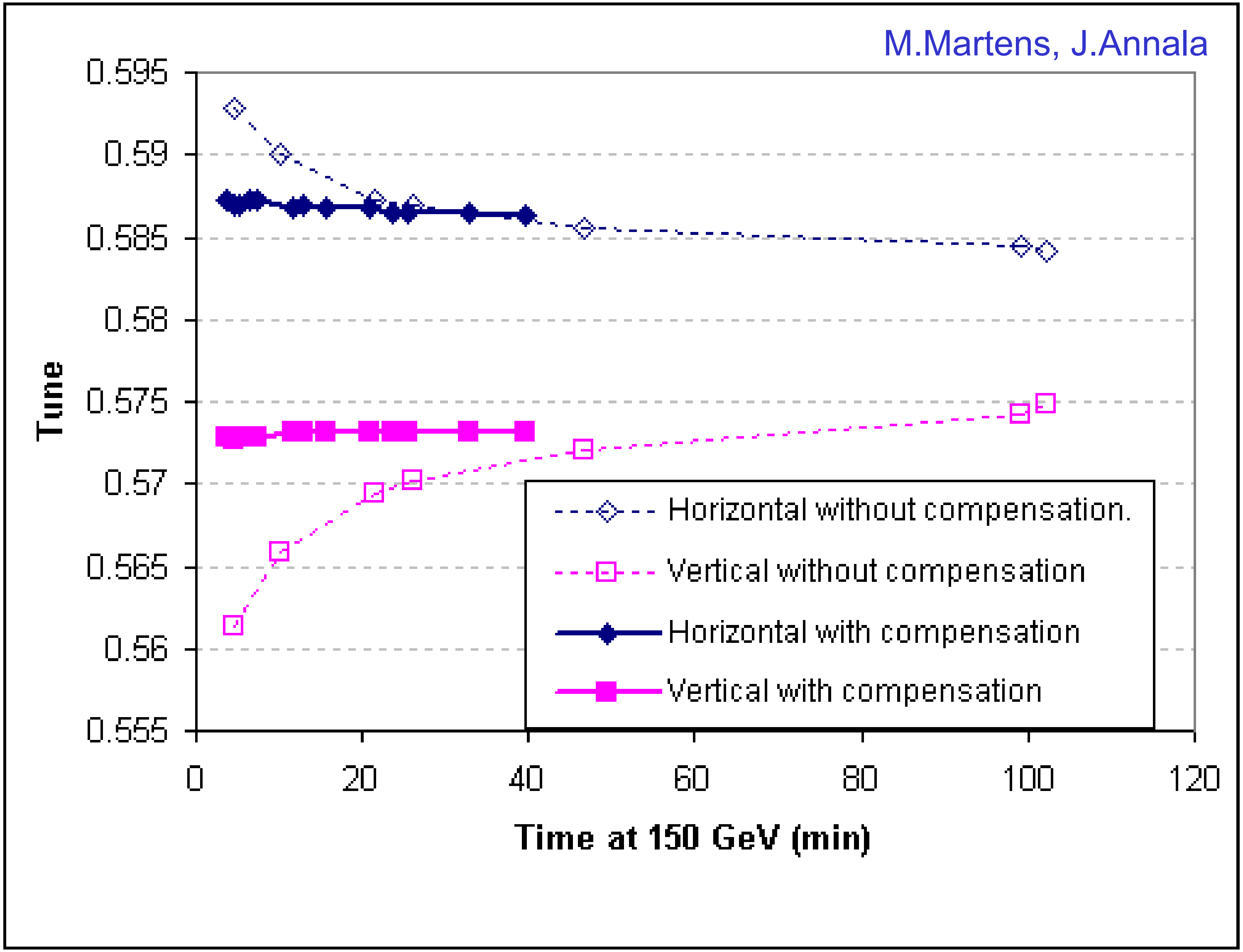
Tune/coupling/chromaticity/orbits

- Tune up is essential for consistent operations …
  - Much effort during "Studies Periods" is actually maintenance (orbit smoothing and tune/coupling/chromaticity adjustments)
- … and for understanding more complicated physics
  - Beam-beam effects, instabilities and dampers, beam lifetimes, beam halo rates, etc. are more difficult to understand when machine parameters drifting.
- Some troubles:
  - Tune/coupling drifts at 150 Gev. (Now compensated.)
  - Tune/coupling snapback on the ramp. (Now compensated.)
  - Chromaticity snapback? (Was measured. Is OK.)
  - Orbit drifts. (Started BPM and smoothing improvements)

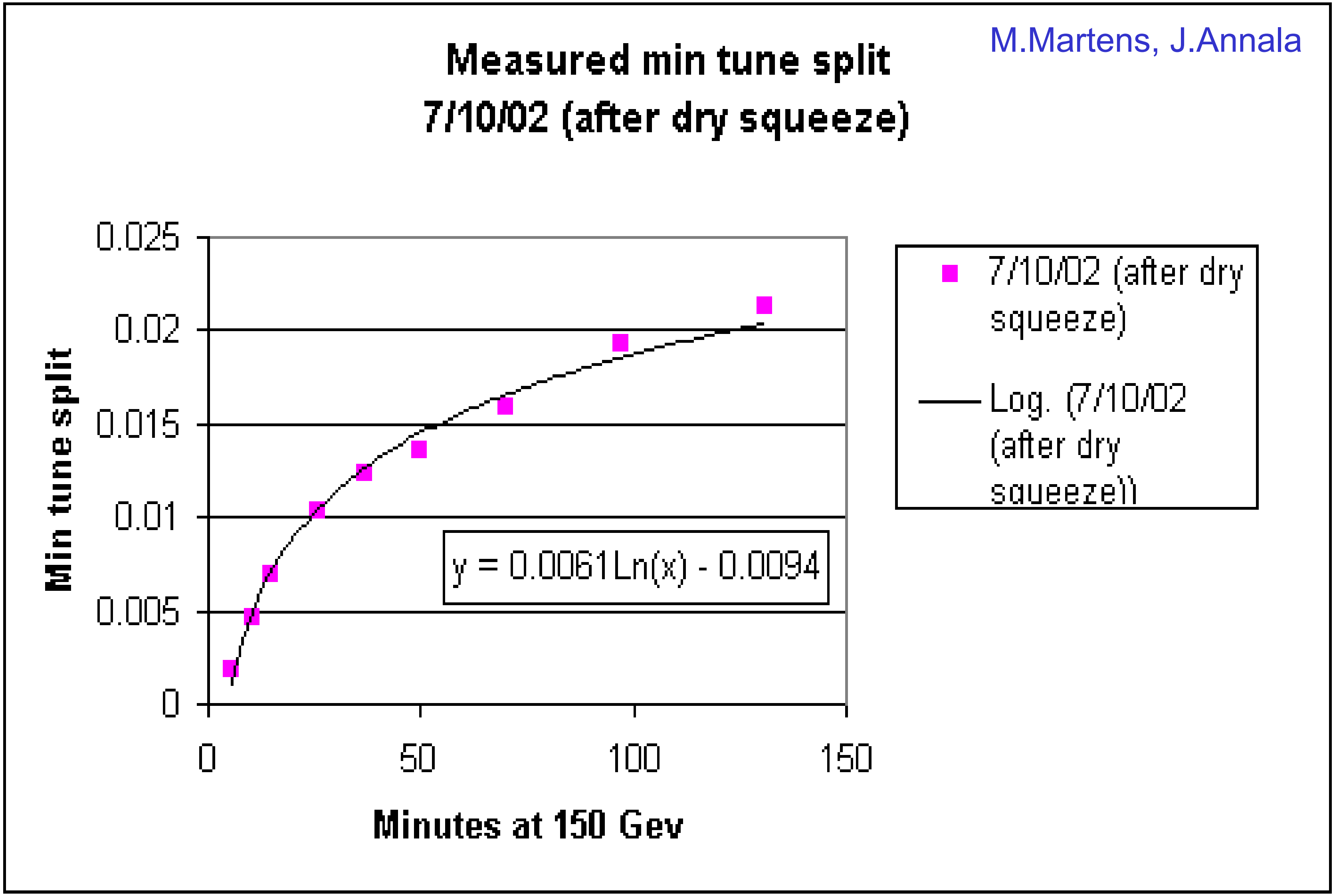
Tune and Coupling Drifts at 150 Gev

- From Run I: Known Chromaticity Drift
  - Chromaticity drift from b_2 component in dipoles
  - Compensated by automatically varying sextupole currents
- New for Run II: Tune and Coupling Also Drift
  - Tune and coupling vary logarithmically after returning to injection energy
  - Makes injection tune-up more difficult
  - Likely caused by persistent currents in the superconducting dipoles and quadrupoles
- Now compensating for Drift
  - Use normal, skew quads similar to chromaticity scheme
  - Tune drift now < 0.001 after 3 hours
  - Coupling drift is not measurable

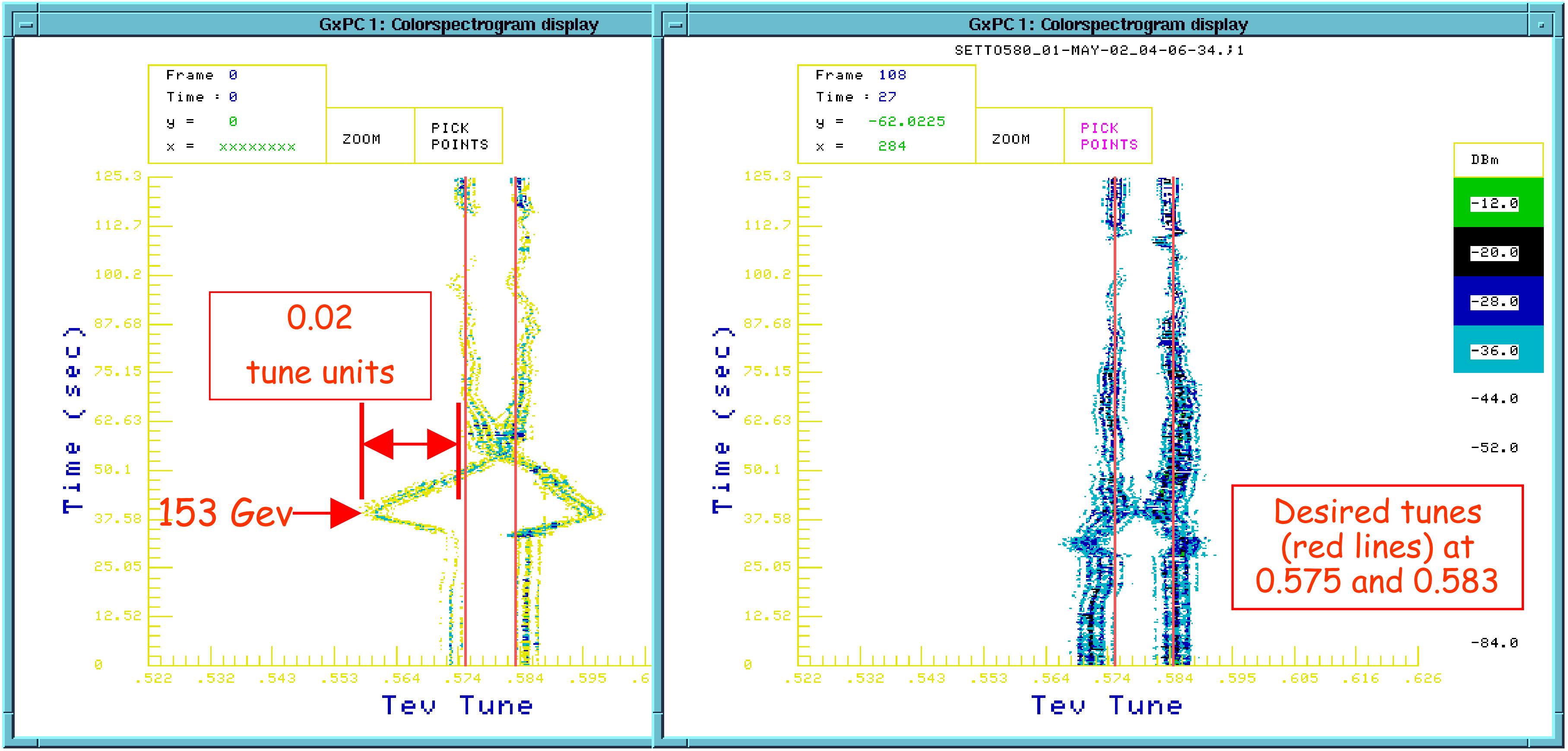
Tune Drift @ 150 Gev



Coupling Drift @ 150 Gev

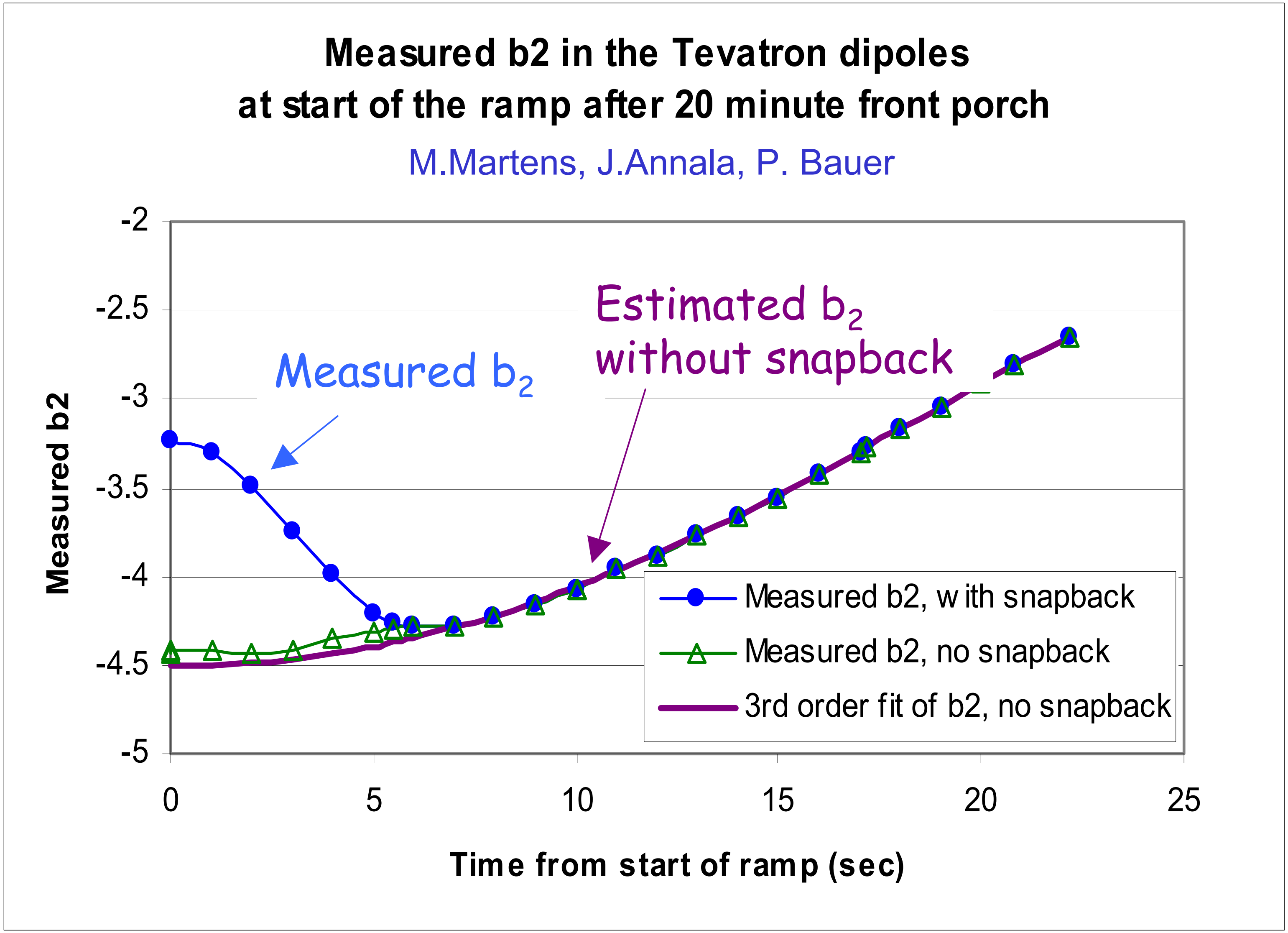


Tune Variations on Ramp/squeeze

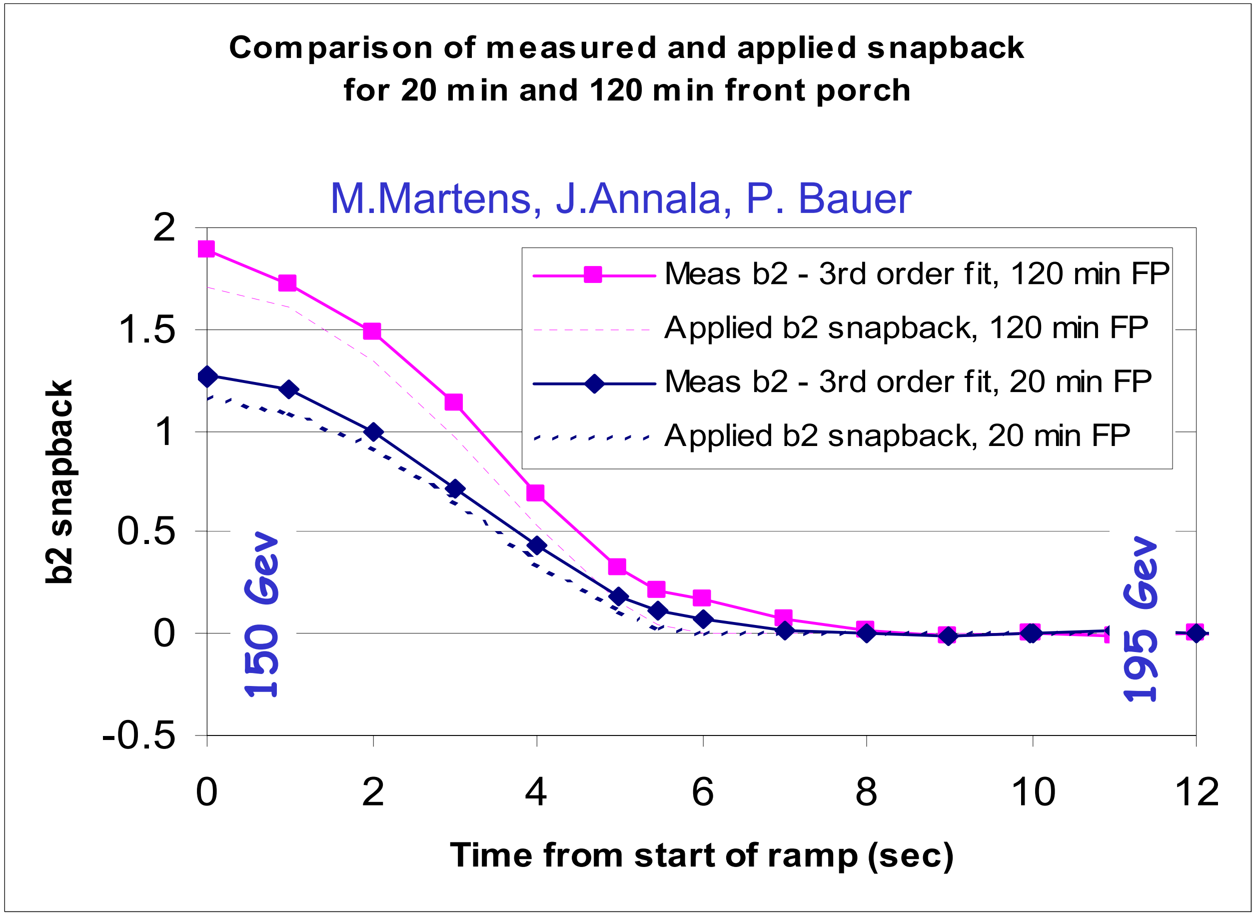


- Near start of ramp (150 → 153 Gev): large tune/coupling excursions
- Tune/coupling changes of (0.02 tune units, 0.02 minimum tune split)
- Variations fixed with <u>additional breakpoint at 153 Gev</u> and <u>tune/coupling snapback correction</u> at start of ramp.

Chromaticity Snapback Measurements

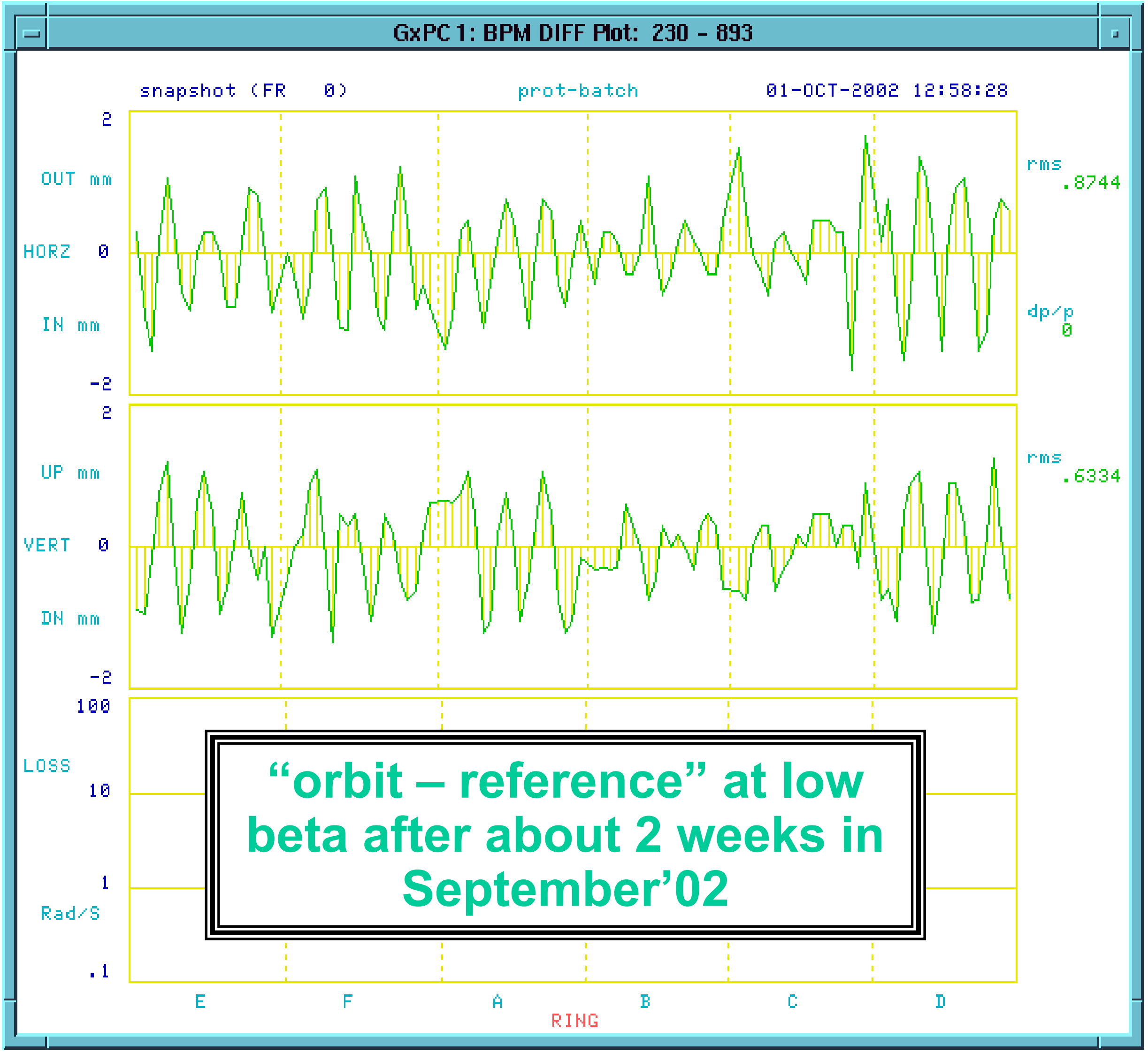


Chromaticity Snapback Compensation



b_2 snapback is correctly compensated (for shot setup conditions.)

Orbit Drifts



Tunes, coupling, ξ vary with closed orbits distortions

"Rule of thumb" -- keep orbit drifts under 0.5 mm rms from "silver orbit"

Orbit drifts of that scale occur in 1-2 weeks (see picture)

Requires routine orbit smoothing at 150 Gev, ramp, flat-top, squeeze, and low-beta.

Orbit Smoothing

Goal: monitor orbit positions during shot setups and stores. (BPMs must work with coalesced beam.)

- Standard orbit smoothing procedure
  - Works well. (But some correctors near maximum strength.)
  - Requires uncoalesced protons
  - Takes time -- several hours for proton only store
  - BPMs are "less accurate" w/coalesced beam during store
- BPM system
  - Tune up/maintenance of BPMs has improved reliability
  - Position measurements not considered good enough with coalesced beam. (Under investigation)
  - Improvements are underway (Understanding electronics, removing "PSD" boxes, and BPM testing software)

Tevatron Alignment Measurements

- What are rolls of Tevatron dipoles and quads?
  - How do these affect coupling?
  - How do these affect understanding of lattice functions?
  - Do these contribute to emittance blow-up at injection?
  - Do rolled dipoles affect orbit, and therefore feedowns?
- Alignment Measurement is work in progress
  - Some dipoles with ~ 8 mrad roll, quads with ~ 4 mrad roll
  - Magnets typically rolled in same direction
- Additional measurements in Jan 2003 shutdown
  - Used a "portable tilt-meter" for quick roll measurements
  - Analysis still pending, but definite rolls
  - (See sample measurements on next slide)

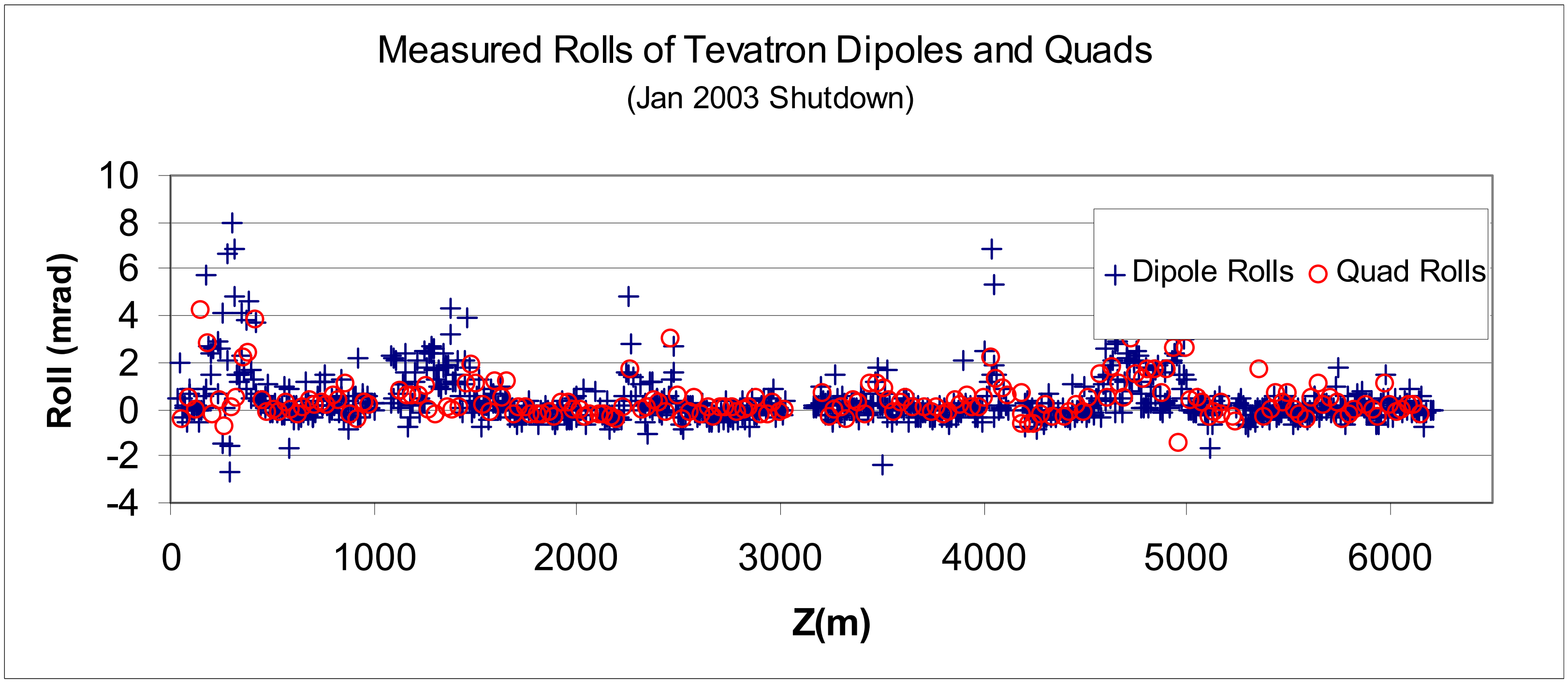
Tevatron Magnet Alignment

Sample data of surveyed rolls on dipoles (and quads)

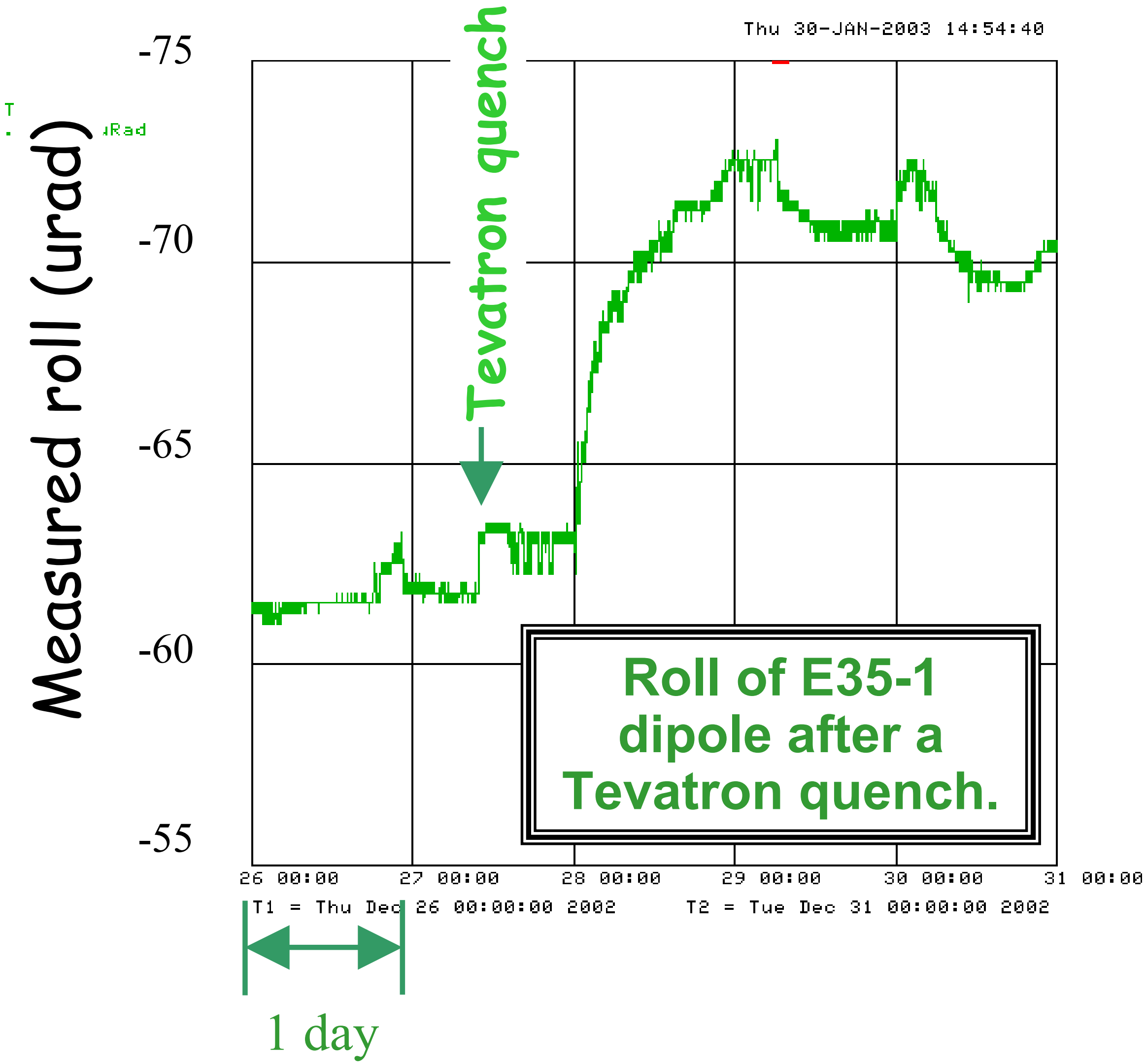
Magnet	Roll (mrad)		Magnet	Roll (mrad)
A19-1(Quad)	-0.67		A23-1(Quad)	2.41
A19-2	**6.86**		A23-2	1.65
A19-3	1.76		A23-3	3.95
A19-4	-4.44		A23-4	0.71
A19-5	-1.94		A23-5	4.89
A21-1(Quad)	0.19		A24-1(Quad)	2.98
A21-2	**8.67**		A24-2	1.49
A21-3	**8.38**		A24-3	0.81
A21-4	4.81		A24-4	1.17
A21-5	1.19		A24-5	3.70
A22-1 (Quad)	0.44		**A25-1 (Quad)**	**3.68**
A22-2	1.06		A25-2	0.60
A22-3	1.49		A25-3	0.33
A22-4	2.33		A25-4	0.14
A22-5	4.44		A25-5	0.37

Tevatron Magnet Alignment

- Measured rolls of dipoles and quads during Jan 2003 shutdown.
- Used "portable tilt-meter" for quick measurements
- Data roughly consistent with vertical dipole corrector strengths
- Dipoles rolled 4 mrad gives ~0.5 mm "scalloped" vert orbit
- Coupling from one quad rolled 4 mrad gives min tune split ~0.0025



Motion of Tevatron Dipole



Newly added a tiltmeter to a Tevatron dipole.

Observed 10 urad roll after a quench

Still watching!!

Larger rolls on other dipoles?

Long term drifts?

Beam-beam Interactions

Slides related to beam-beam interactions

- Pbar intensity loss during store ~25%
- Pbar intensity loss during Pbar only store
- Pbar lifetime at 150 Gev
  - Pbar beam lifetime versus emittance
  - Lifetime versus chromaticity
- Progress/plan for improving pbar lifetime at 150 Gev
  - Smaller pbar emittances from accumulator improvements
  - Reduce injection oscillations (BLT) ⇒ smaller pbar emittances
  - Larger C0 aperture ⇒ Larger helix ⇒ Lower pbar tune shifts
- Beam-beam at 980 Gev
  - Pbar emittance blowup depends on bunch number
  - Measured and predicted bunch-by-bunch pbar tunes
  - Working point tune scans

Beam-beam Interaction As Major Factor

- *Pbar transfer efficiency strongly depends on N_p, helix separation, orbits, tunes, coupling, chromaticity and beam emittances at injection*
- *Summary of progress with beam-beam since March 2002:*

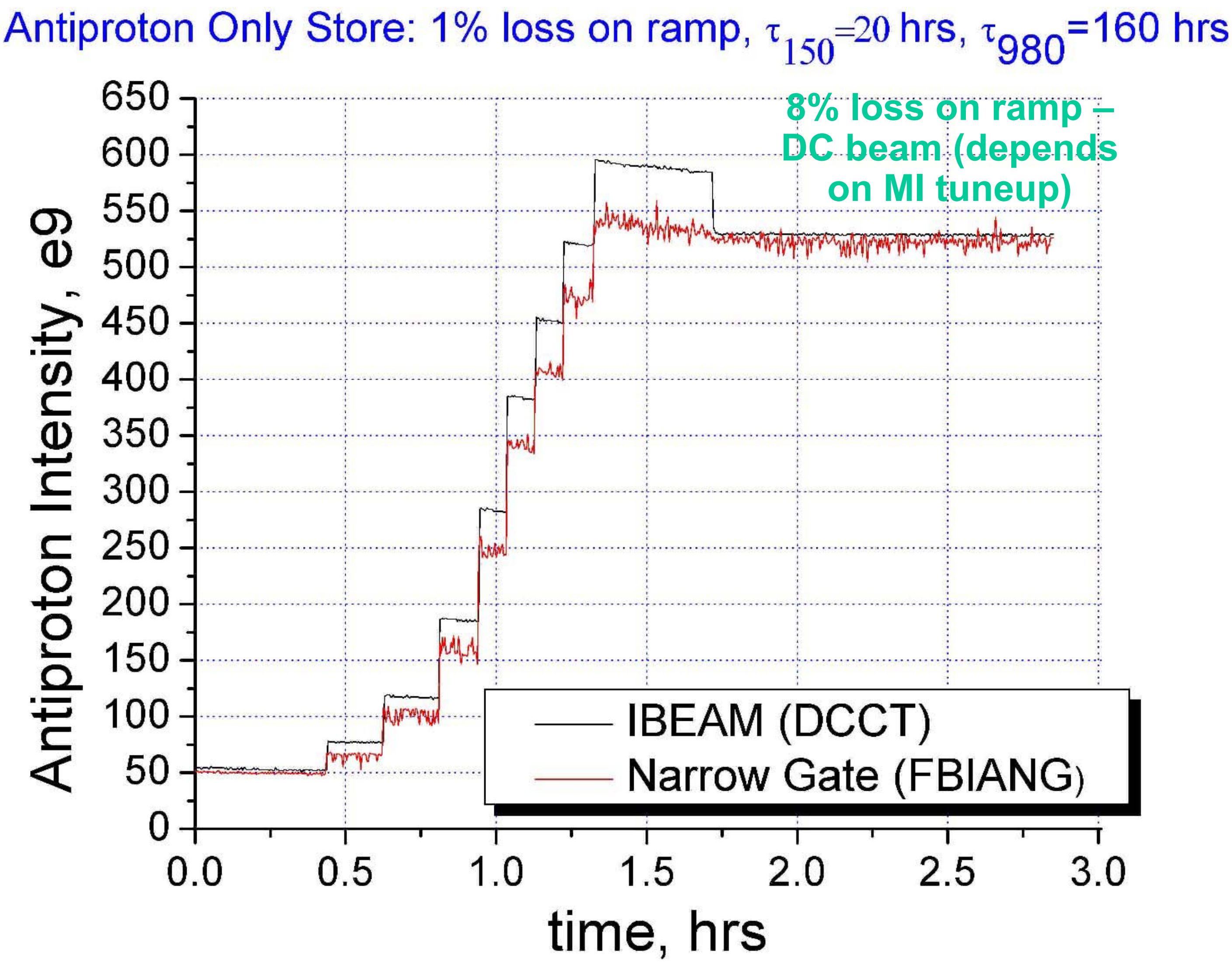
	Mar'02 *	Oct'02 **	Jan'03 ***
Protons/bunch	*140e9*	*170e9*	*180e9*
Pbar loss at 150 GeV	*20%*	*9%*	*4%*
Pbar loss on ramp	*14%*	*8%*	*12%*
Pbar loss in squeeze	*22%*	*5%*	*3%*
Tev efficiency Inj→low beta	*54%*	*75%*	*75%*
Efficiency AA→low beta	*32%*	*60%*	*62%*

* *average in stores #1120-1128*

** *average in stores #1832-1845*

*** *average in stores #2114-2153 (9 stores)*

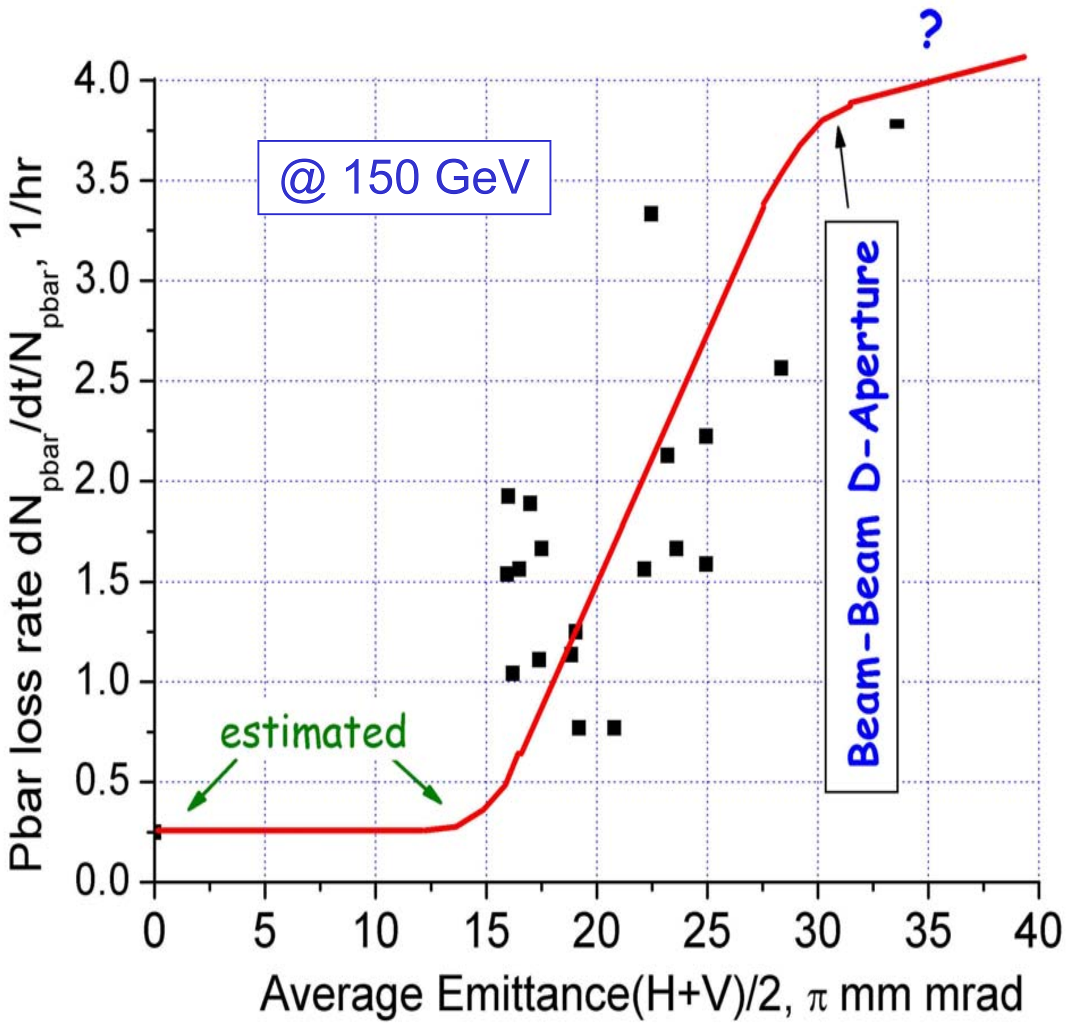
Beam-beam Effects: Pbar Only



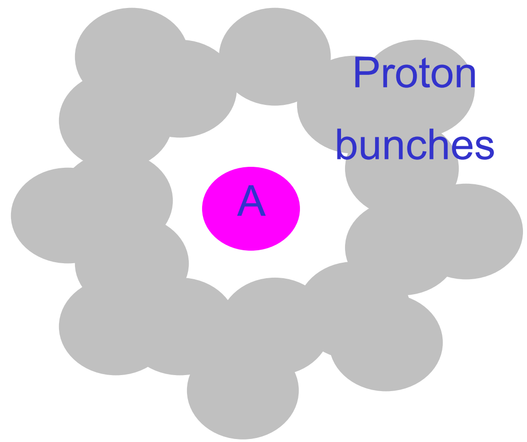
Lifetime Issues at 150 Gev

- Poor Pbar lifetime at 150 Gev
  - Depends on emittances, N_p, ξ, and bunch number
  - Lifetime ~ 0.5-1.0 hrs
  - Original injection helix has been modified, separation increased and optimized to fit tight C0 aperture ("new-new helix")
  - Replace lambertsons @ C0 – gain 25 mm vertically
  - Modify high β section at A0 formerly used for fixed-target extraction
- Poor proton lifetime on helix ~ 2 hr
  - depends on chromaticity
  - Instability prevents lower chromaticity (now 8)

Antiproton Lifetime at 150 Gev

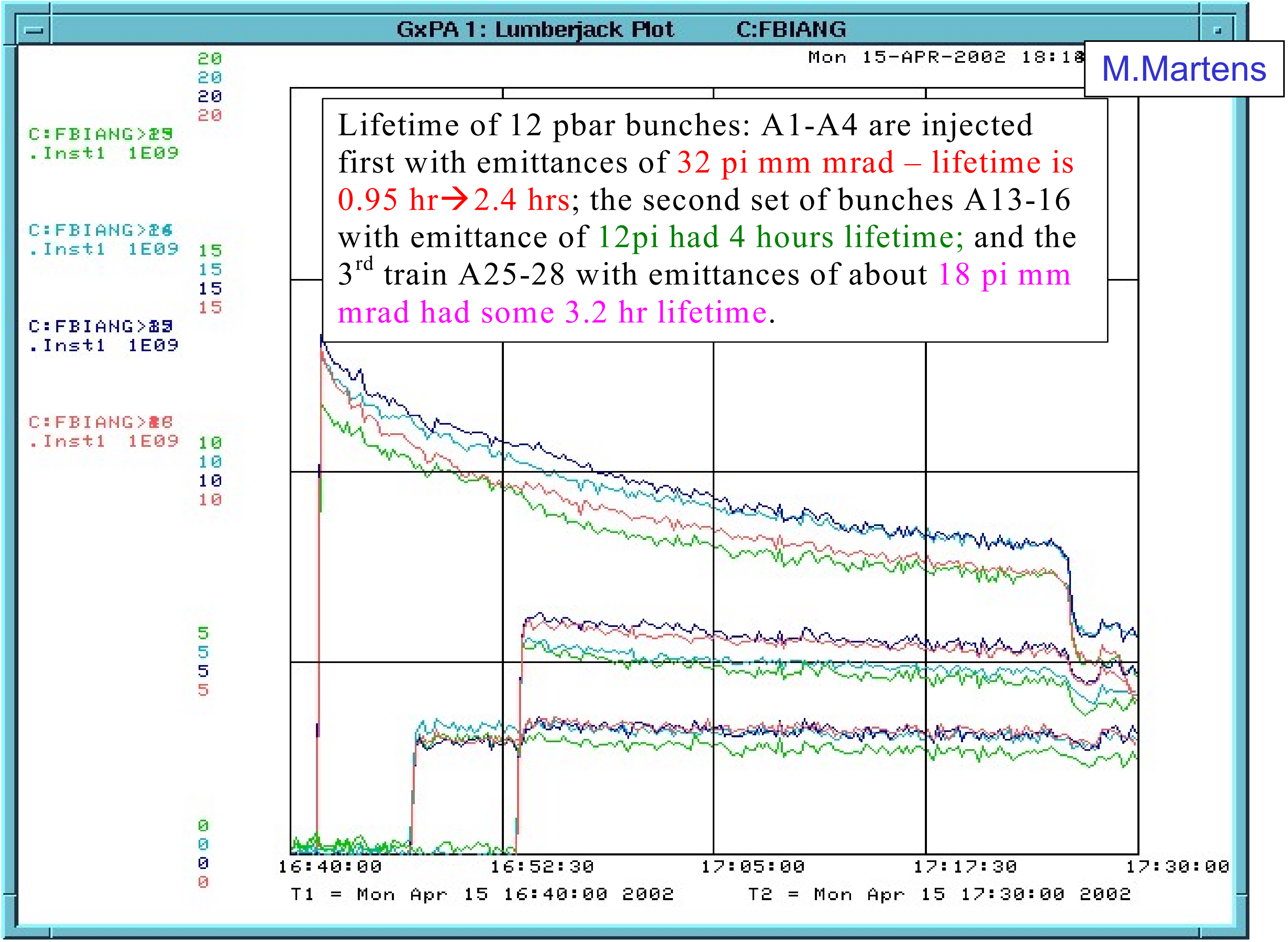


Pbar losses depend strongly on pbar emittances and N_p

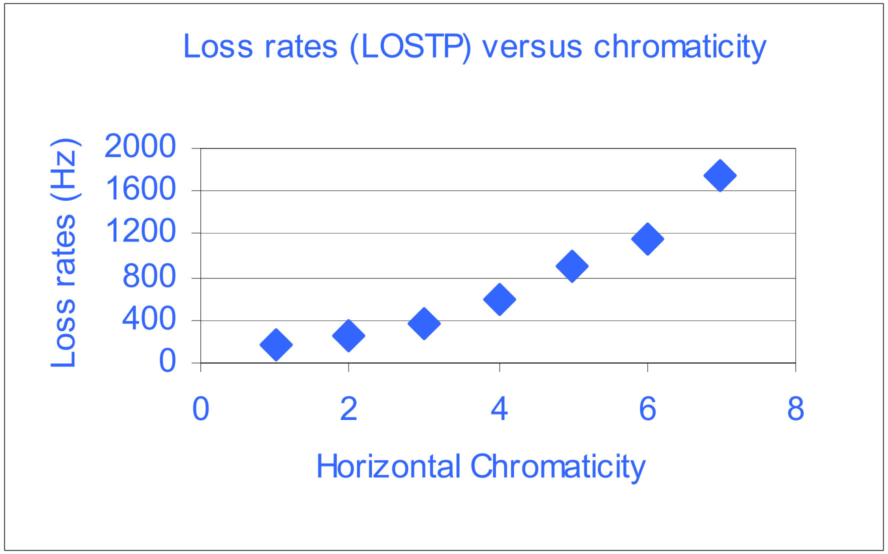


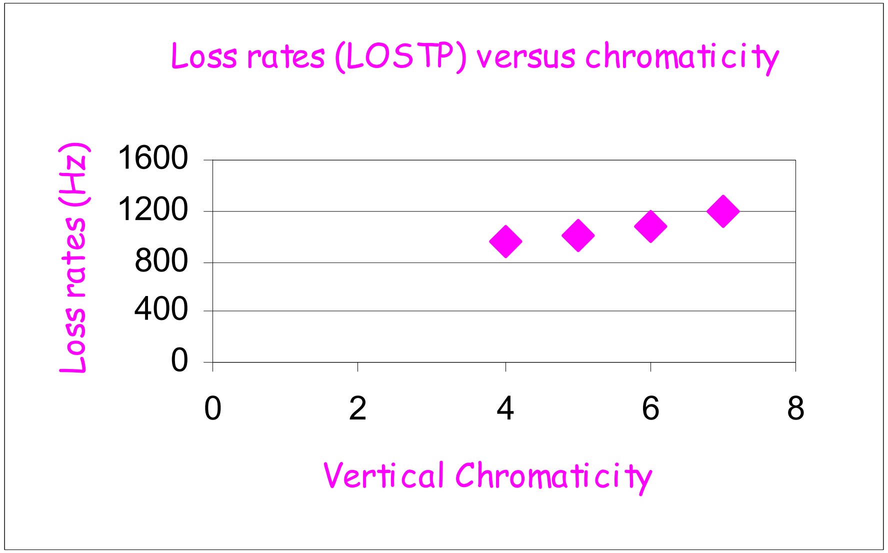
Proton Beam as "Soft Donut Collimator"

Beam-beam @ Injection Vs Emittance



Lifetime and Chromaticity at 150 Gev





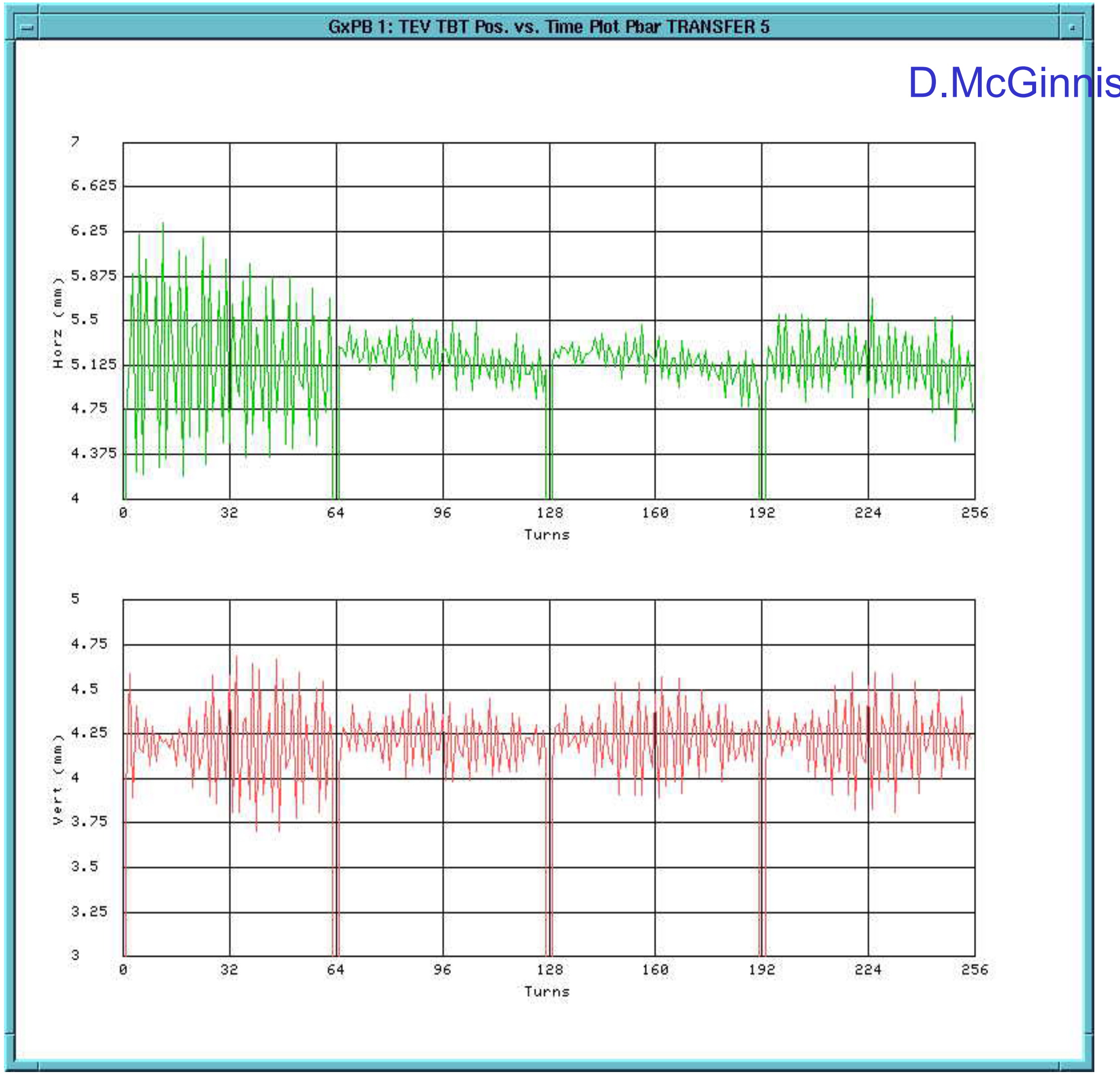
Measured loss rates as function of chromaticity (with protons on the pbar helix)

- Lower chromaticity is better for lifetime
- Instabilities appear ξ < 3-4
- Run with $\xi_H = 8$, $\xi_V=8$ to avoid instabilities
- Dampers allow us to lower chromaticity and improve lifetime

Attacking the Beam-beam Effects

- Smaller emittances from AA ("AA shot lattice")
- Reduced injection errors
  - Beam Line Tuner
- Better control of orbits / tunes / coupling
  - Tunes up the ramp
  - Tune and coupling drift at 150 Gev
  - Orbit smoothing
- Larger injection helix
  - C0 Lambertson replacement
  - New Separator settings

Diagnostics: Beam Line Tuner

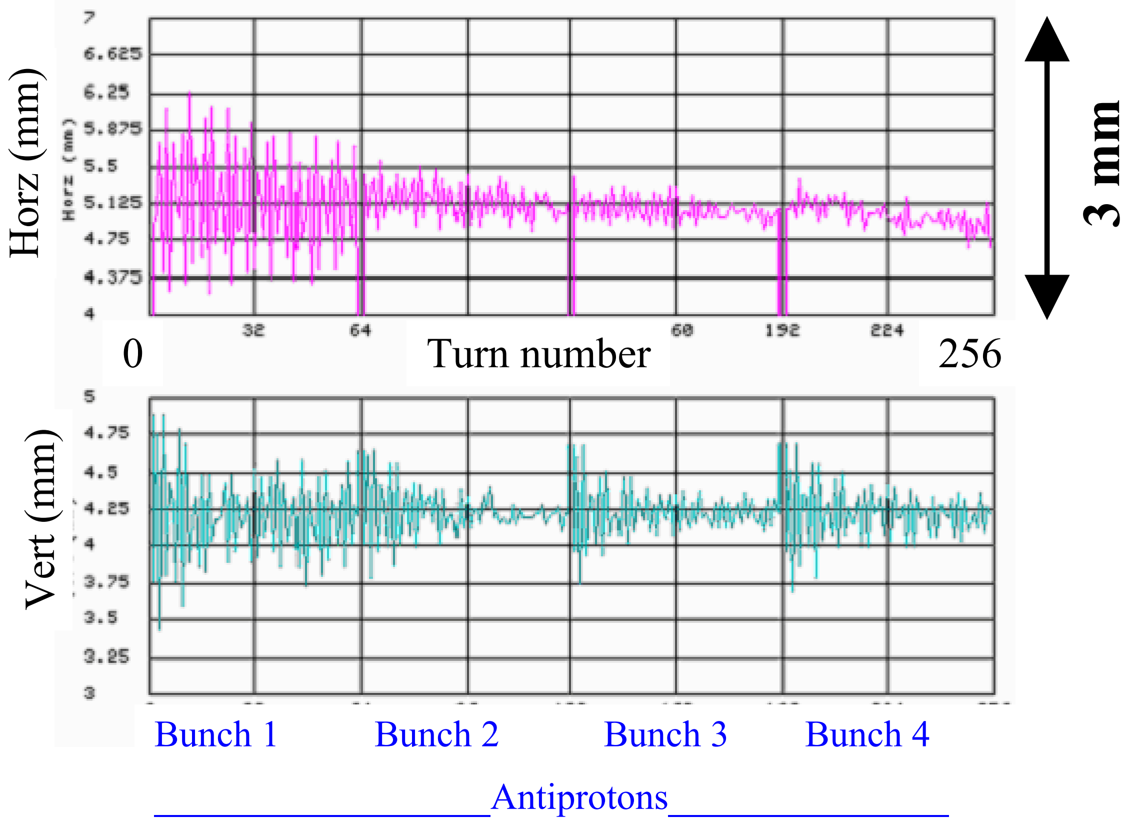


Consists of striplines, DAQ, software and dipole correctors in A1/P1 lines

Old version (RF integrator) was too sensitive to time jitter (now improved but not in use)

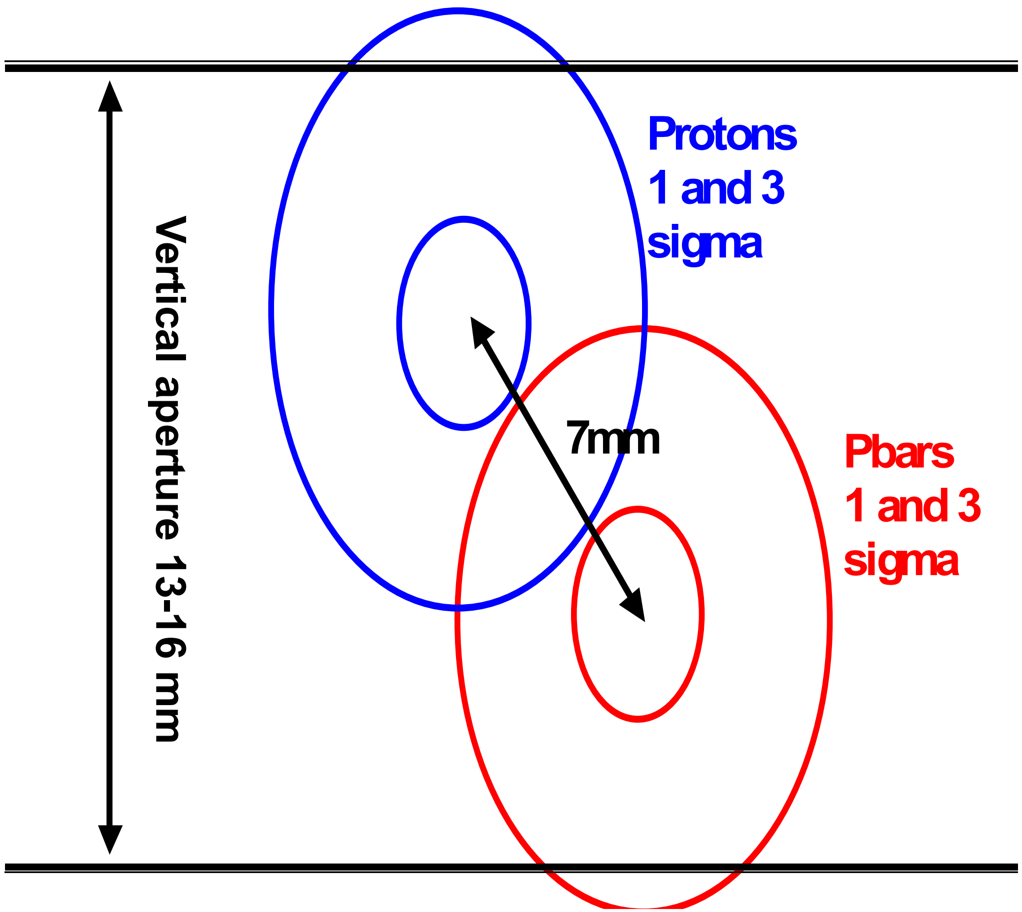
New version based on segmented memory scope (now operational)

Injection Oscillations in Tevatron



- Turn-by-turn position monitor, (and bunch-by-bunch for pbar)
- Use to tune up injection closure
- 1 mm corresponds to roughly 3-4π emittance blowup
- Improved Pbar emittance blowup by ~3-5π

C0 Lambertson Replacement



Proton and pbar beam position and sizes on the helix at the location of C0 Lambertson

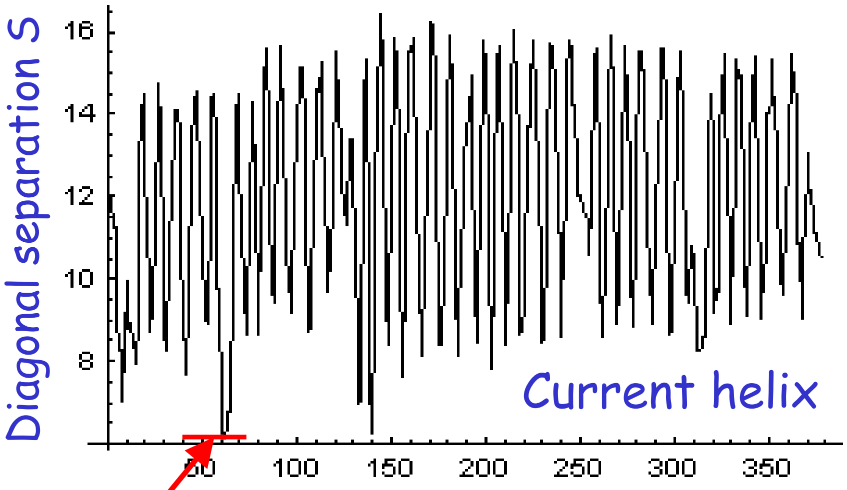
Pbar lifetime depends on emittances and helix size.

C0 Lambertson is severest aperture restriction. (See picture)

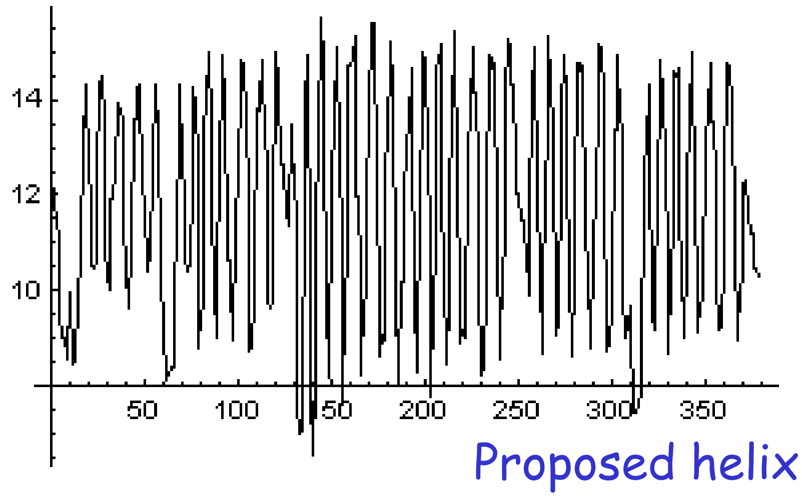
Design injection helix modified and optimized to fit tight C0 aperture ("new-new helix")

(Jan 2003)
Replace C0 Lambertsons
Gain 25 mm vertically

Helix Improvement



Distance from B0



Distance from B0

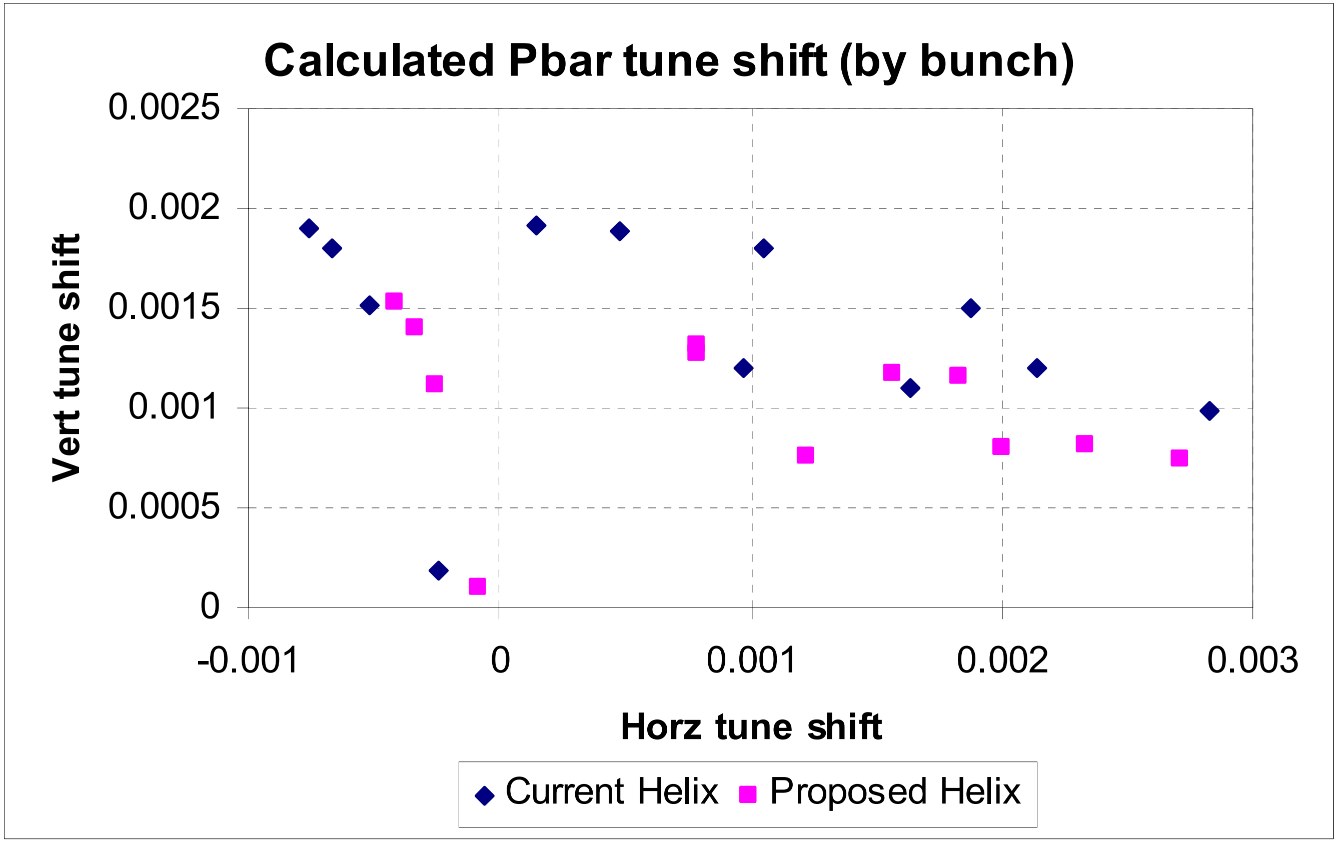
Aperture limitation at C0

$$S = \sqrt{(\Delta x / \sigma_x)^2 + (\Delta y / \sigma_y)^2}$$

Increasing proton/pbar helix separation

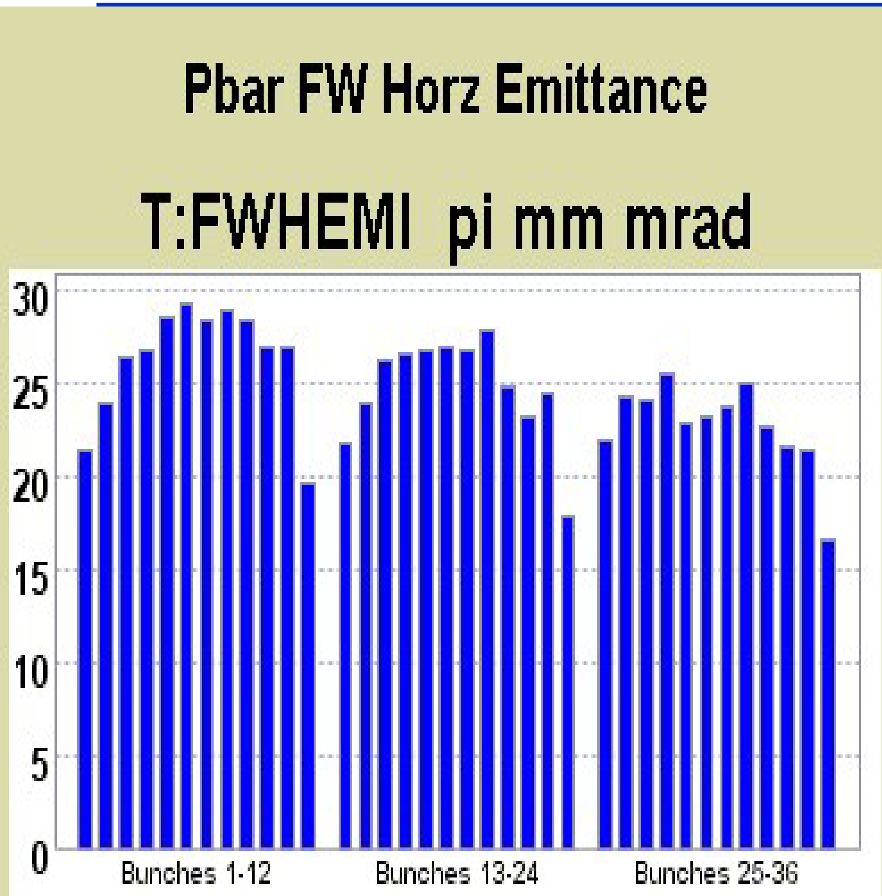
- Replace C0 Lambertson with MI magnets
- Increase vertical aperture at C0 from ~15mm -> 40 mm (but only ~30% larger helix due to other aperture limitations.)
- Modify helix to increase min separation, S_{min}, from 5.5 to 6.6

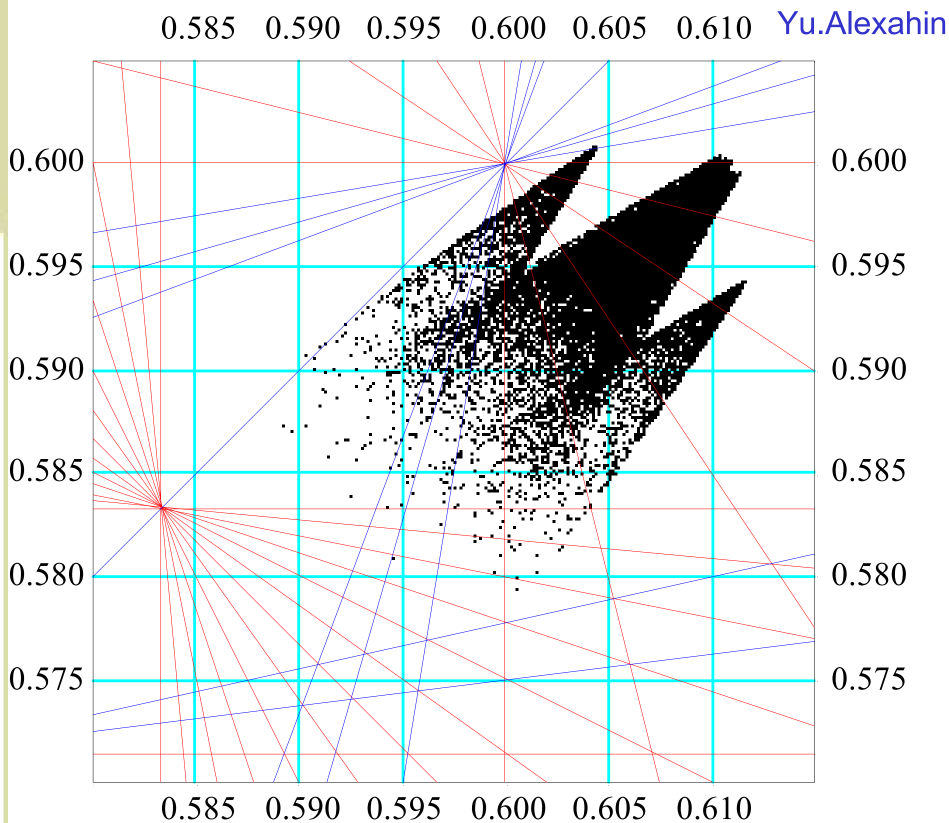
Beam-beam Tune Shift Reduction



Proposed injection helix (with larger C0 aperture) will reduce small amplitude tune shift of pbars

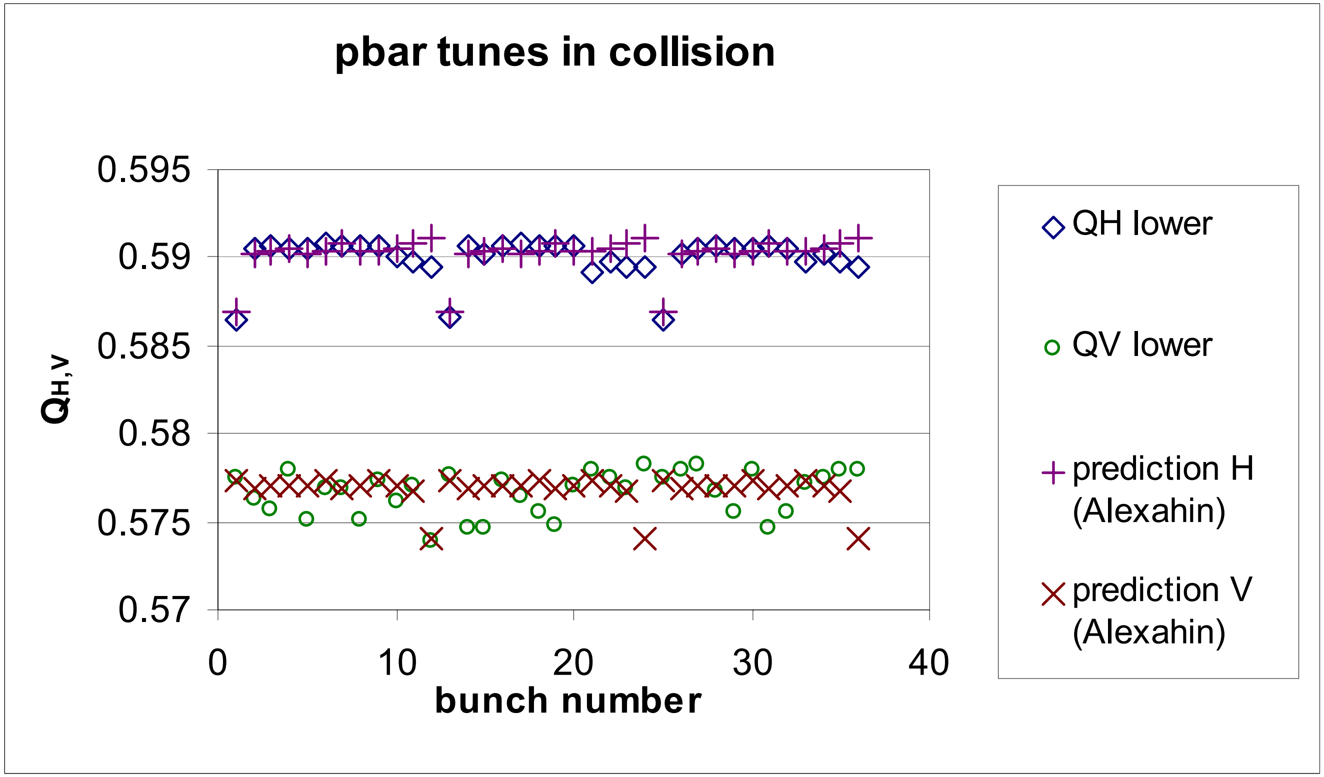
Beam-beam Effects at 980 Gev





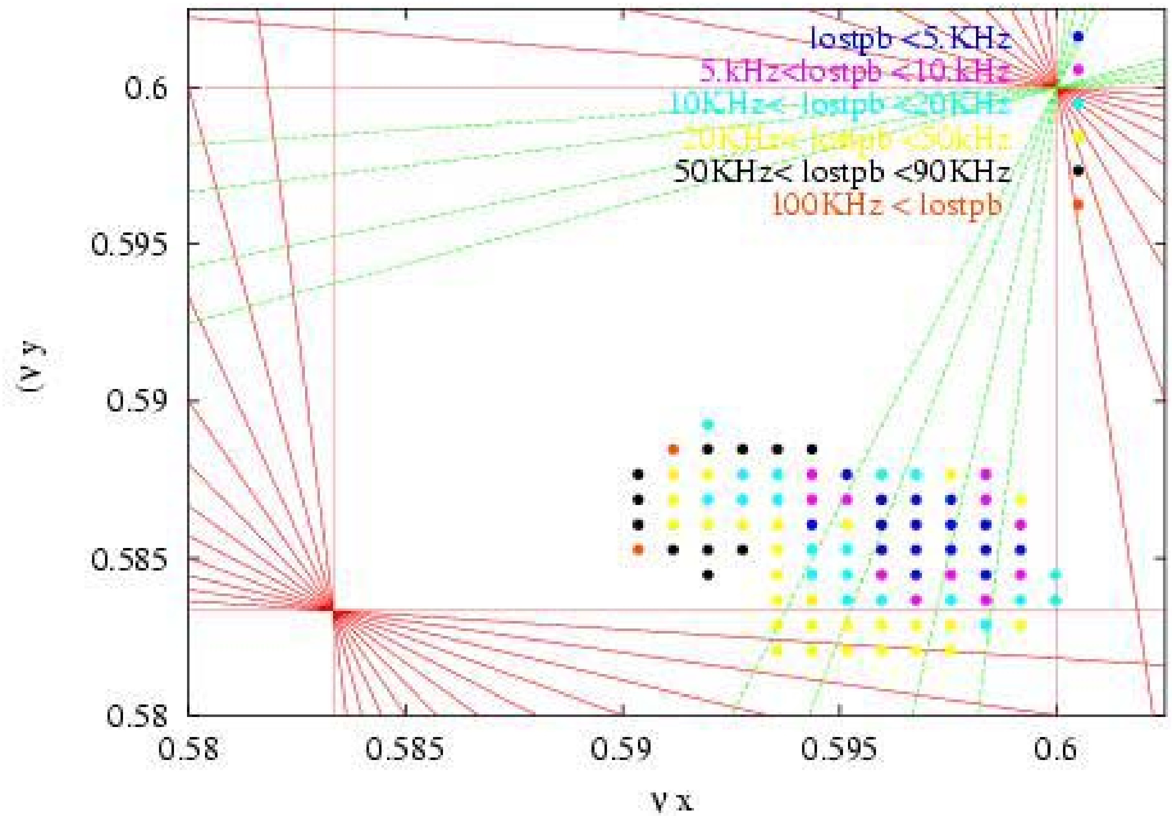
- Pbar bunches near abort gaps have better emittances and live longer
- Emittances of other bunches are being blown up to 40% over the first 2 hours – see scallops over the bunch trains
- The effect is (and should be) tune dependent - see on the right
- Recently, serious effects of pbars on protons – completely unexpected

Beam-beam Tune Shift Measurement



- Measured and predicted pbar tune shift as function of bunch number at collisions.
- Used gated "tickler" to excite individual pbar bunches and measured tunes with schottky pickup

Working Point Tune Scans



Measured pbar halo loss rate during collisions as function of pbar tunes

Instabilities and Dampers

Slides related to instabilities and dampers

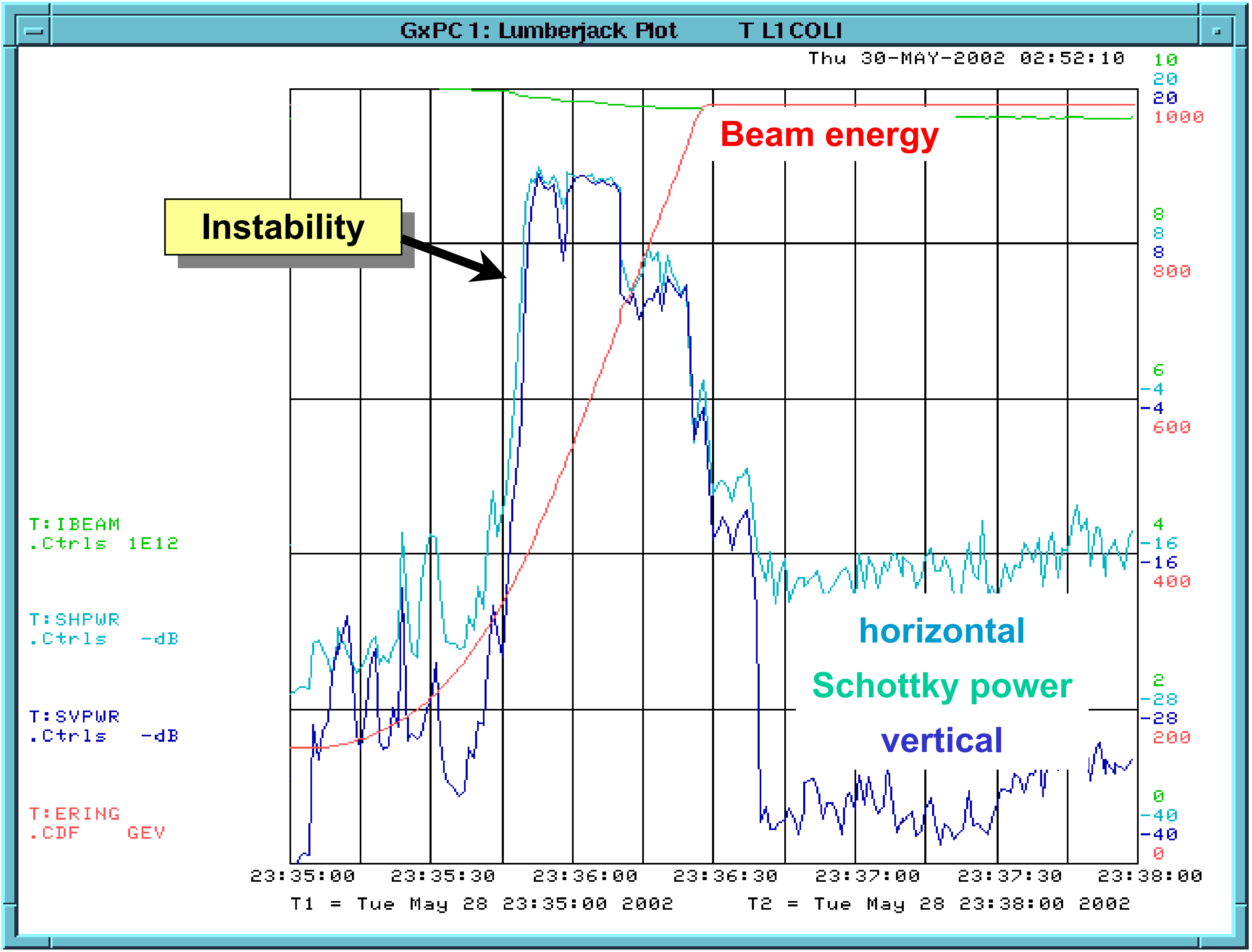
- Proton Transverse Instability
  - Head-Tail?
  - Instability on ramp
  - Head-tail instability measurement with TBT
- Tevatron Transverse Dampers
  - Schematic outline of transverse dampers
  - Demonstration of damping
- Tevatron Longitudinal Dampers
  - Dancing bunches
  - Schematic outline of longitudinal dampers
  - Demonstration of damping
  - Fixed bunch length blow-up during store

Proton Transverse Instability

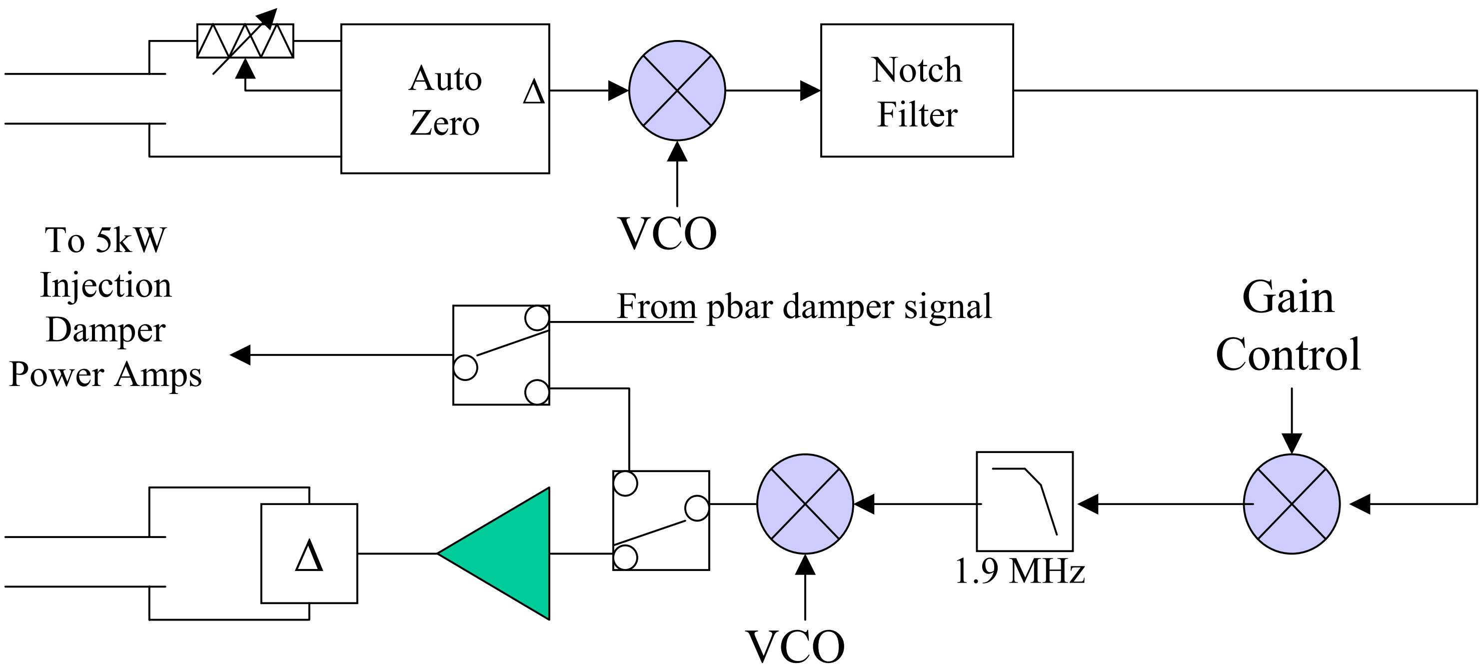
- Intensity-dependent: appears above ~170E9/bunch
  - Single bunch weak head-tail phenomenon
- Can occur at 150 GeV, up the ramp, at 980 GeV
  - Schottky powers rise quickly
  - p/pbar emittances blow up for individual bunches
- Try to prevent/control instability via:
  - Raising chromaticities (8 @150, >20 at 980)
  - Adjusting coupling and tunes
  - Limiting p intensity to ~240E9/bunch at injection
  - More pbars help to stabilize protons
- Constructed bunch-by-bunch transverse dampers
  - hor chromaticity at injection lowered 8→ 2 at 150
  - ver chromaticity at injection lowered 8→ 4 at 150

… but the problem is not solved yet…

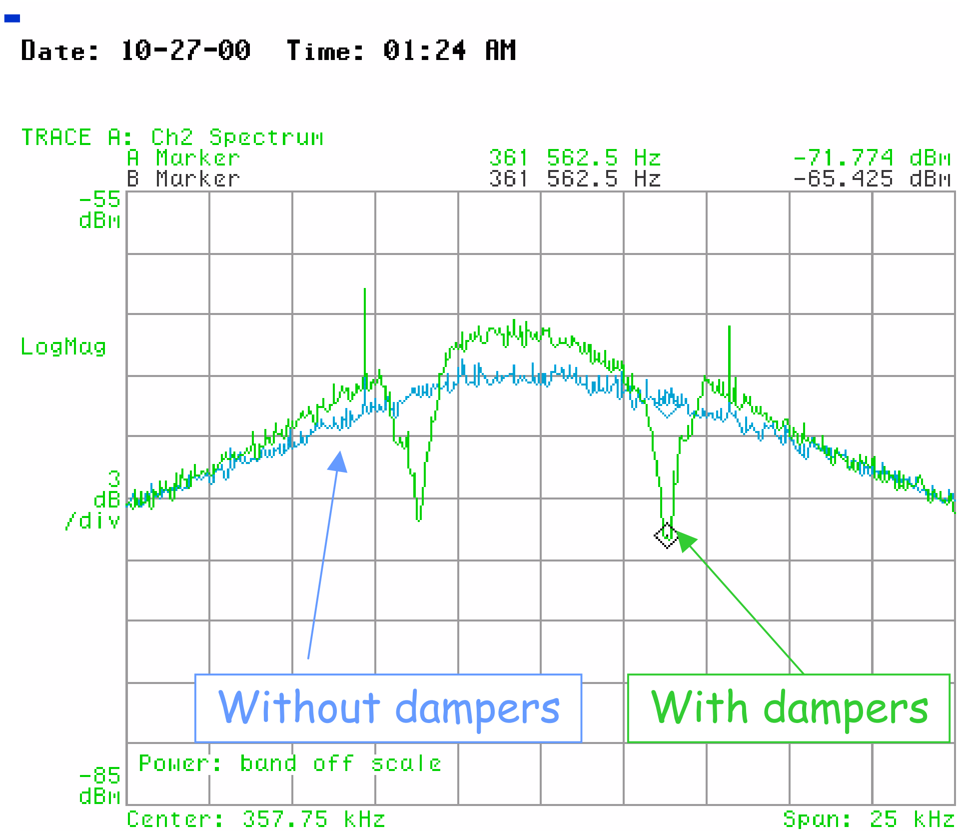
Transverse Instability On Ramp



TeV Transverse Damper



Tev Transverse Damper



- Damper Hardware completed
- See suppression of tune lines
- Can reduce ξ at injection with damper on. Beam is unstable otherwise.

Transverse damper hardware works.

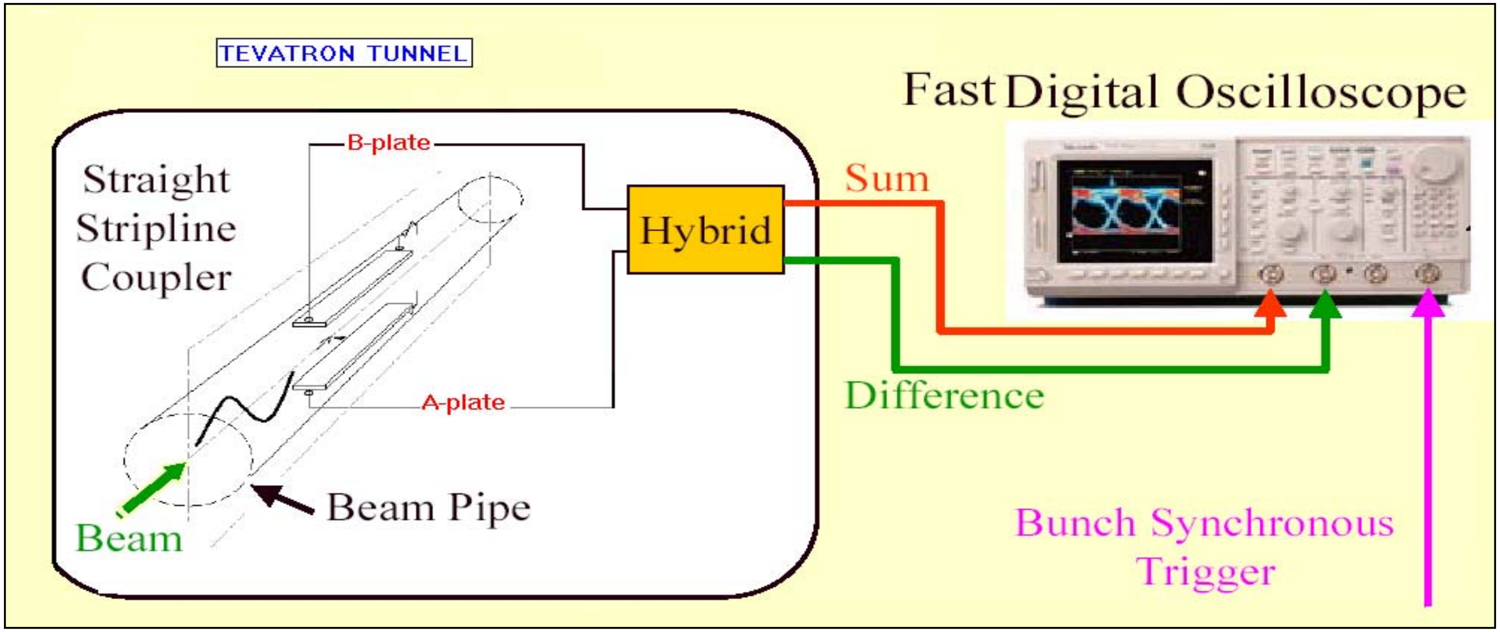
Dampers turned on after 36 proton bunches are injected.

With dampers can lower ξ_h from 8 $\Rightarrow$ 2, ξ_v from 8 $\Rightarrow$ 4 …

… which improves proton & pbar lifetime …

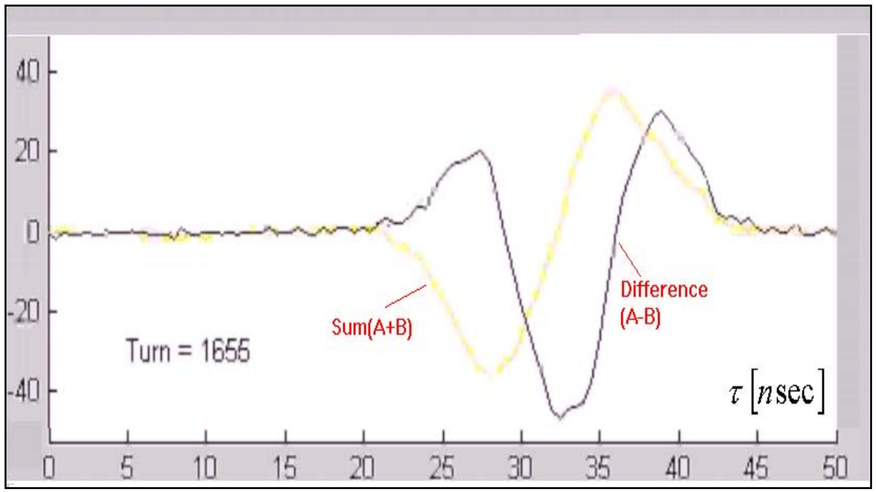
… which reduces pbar beam loss at 150 Gev from ~10% to ~2%.

Head-tail Monitor



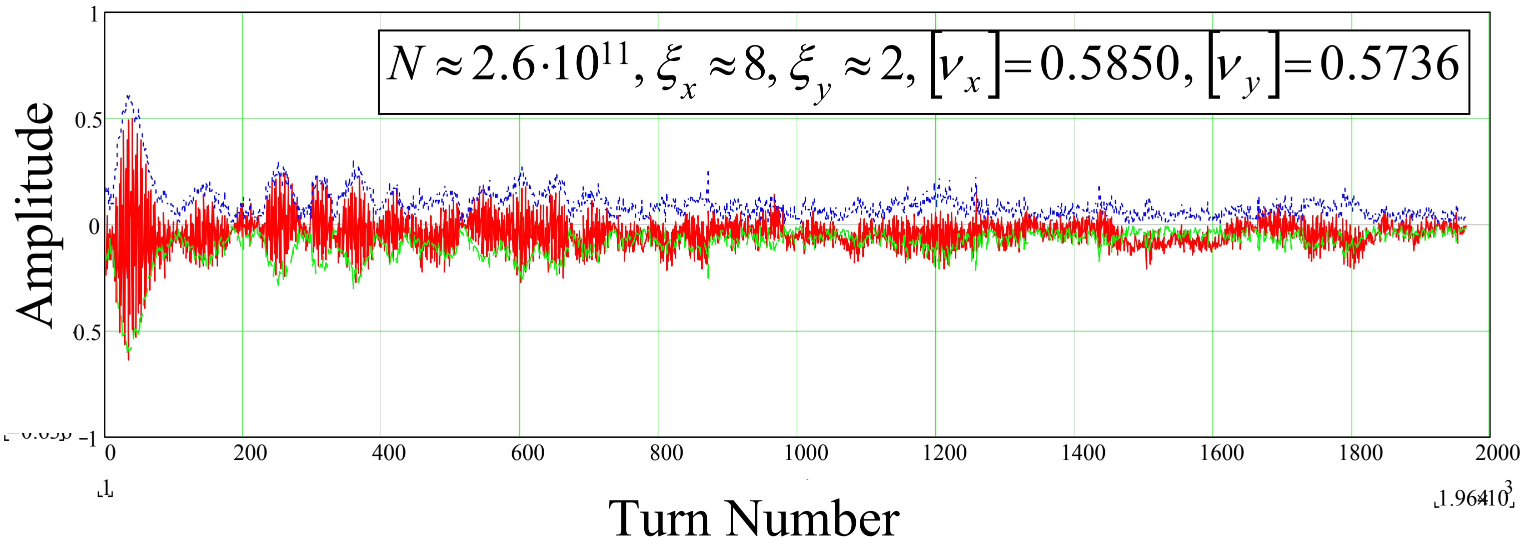
Longitudinal configuration of the transverse dipole moment oscillations can be measured as

$$\bar{Y}(n,\tau)=\frac{A}{2}\cdot\frac{A(n,\tau)-B(n,\tau)}{A(n,\tau)+B(n,\tau)}$$



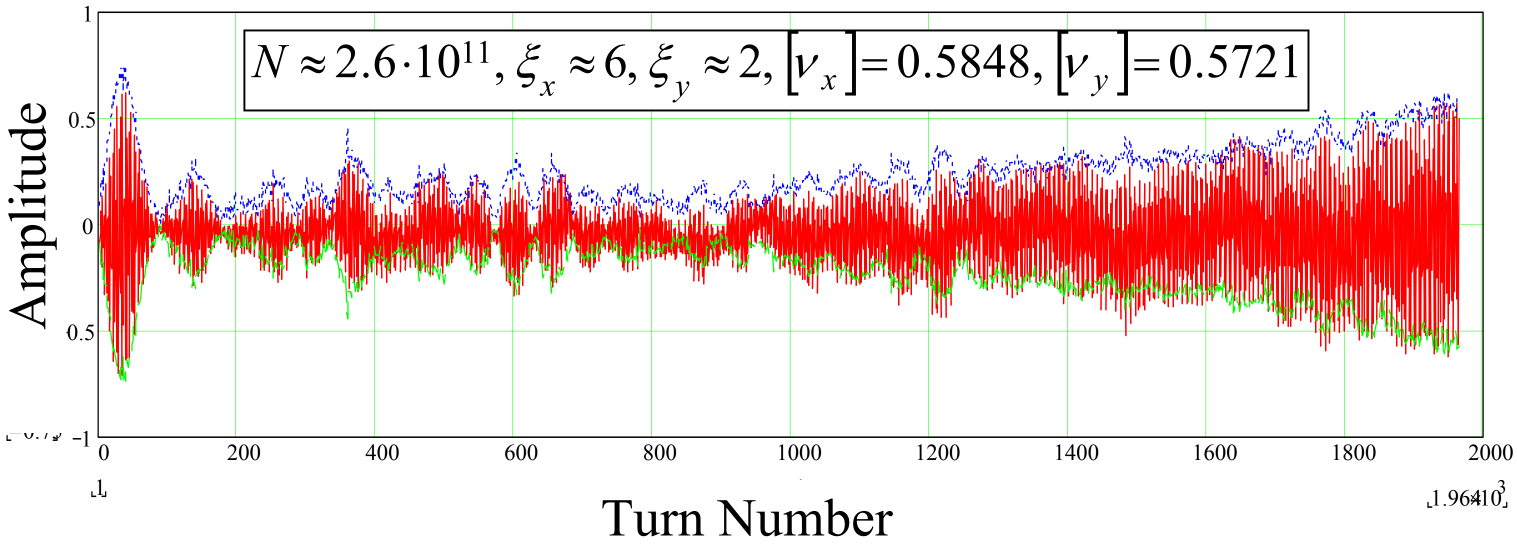
Unstable Head-tail Motion

Observed transverse oscillation for <u>stable</u> conditions
Beam is stable for $\xi_x \approx 8$, $\xi_y \approx 8$
Longitudinal and transverse dampers OFF
N_p= 260E9



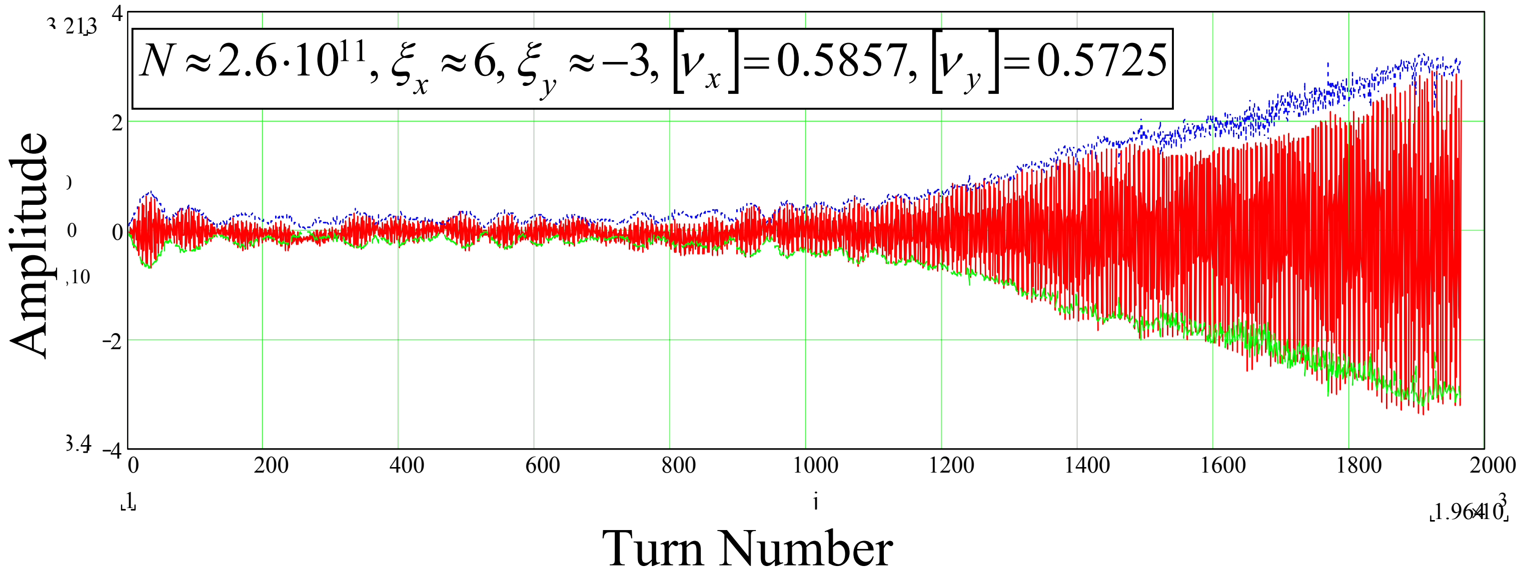
Unstable Head-tail Motion

Developing head-tail instability with <u>dipole</u> configuration
Beam is unstable for $\xi_x \approx 6$, $\xi_y \approx 2$
Longitudinal and transverse dampers OFF
N_p= 260E9

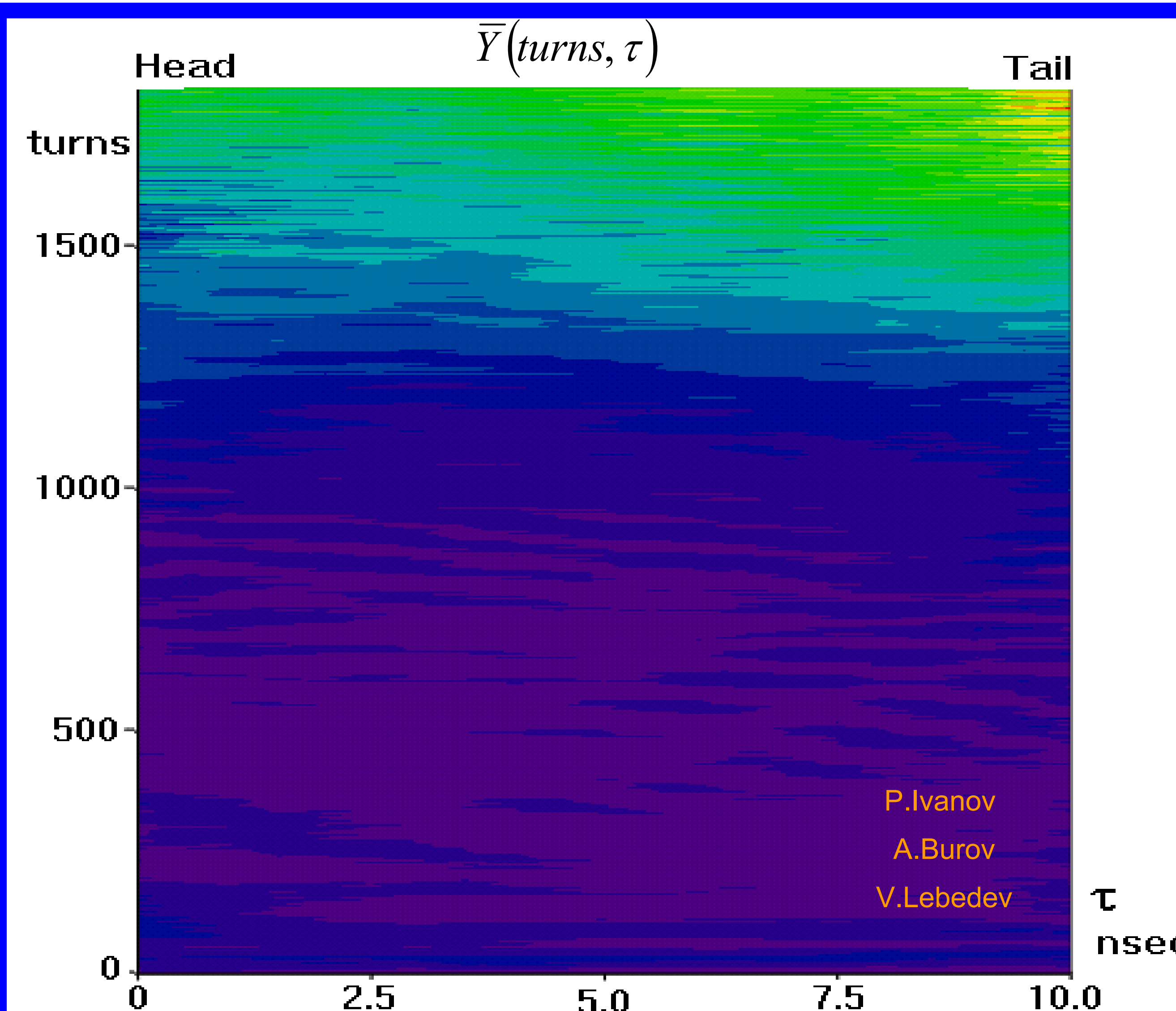


Unstable Head-tail Motion

Developing head-tail instability with <u>monopole</u> configuration
Beam is unstable for $\xi_x \approx 6$, $\xi_y \approx -3$
Longitudinal and transverse dampers OFF
N_p= 260E9



Unstable Head-tail Motion



$E = 150 GeV$

$N_{ppb} \approx 2.6 \cdot 10^{11}$

$\xi_y \approx -3$

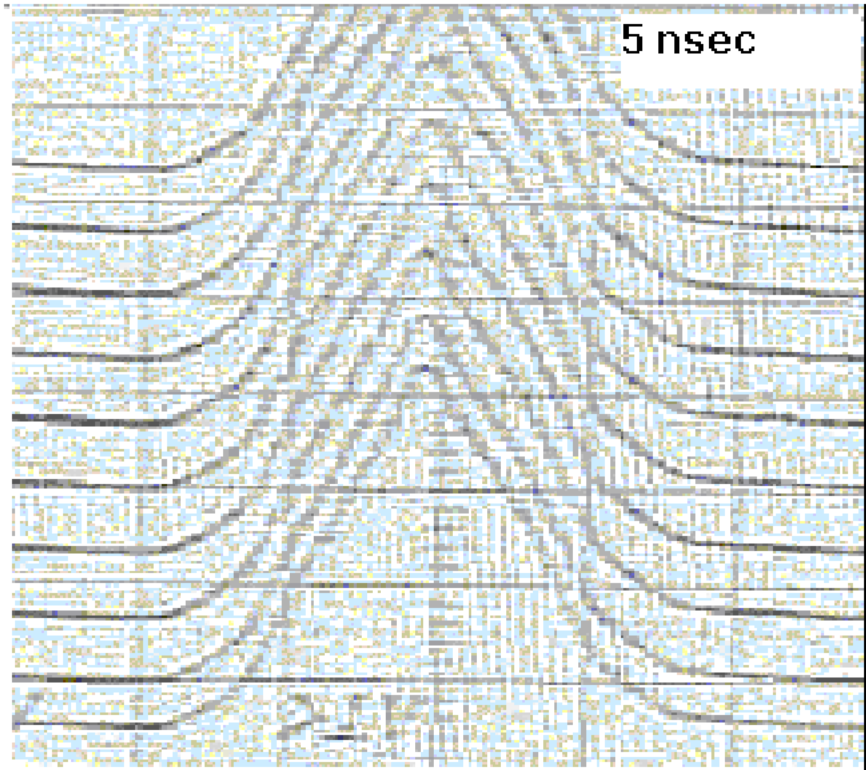
$l_s = 0$

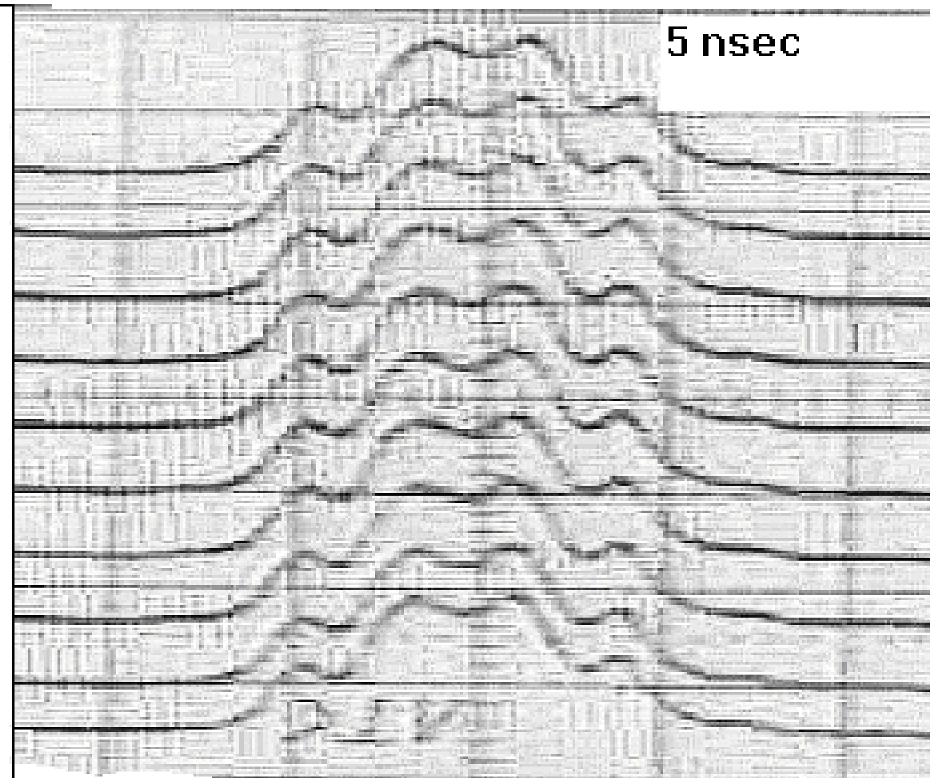
Transverse Instability

- Beam remnants point to coherent betatron mode with ***l=2***

$$N_{ppb} = 2.6 \cdot 10^{11} \left(init.\ beam \right) \qquad \Rightarrow \qquad N_{ppb} = 1.03 \cdot 10^{11} \left(remain.\ beam \right)$$

P.Ivanov, A.Burov



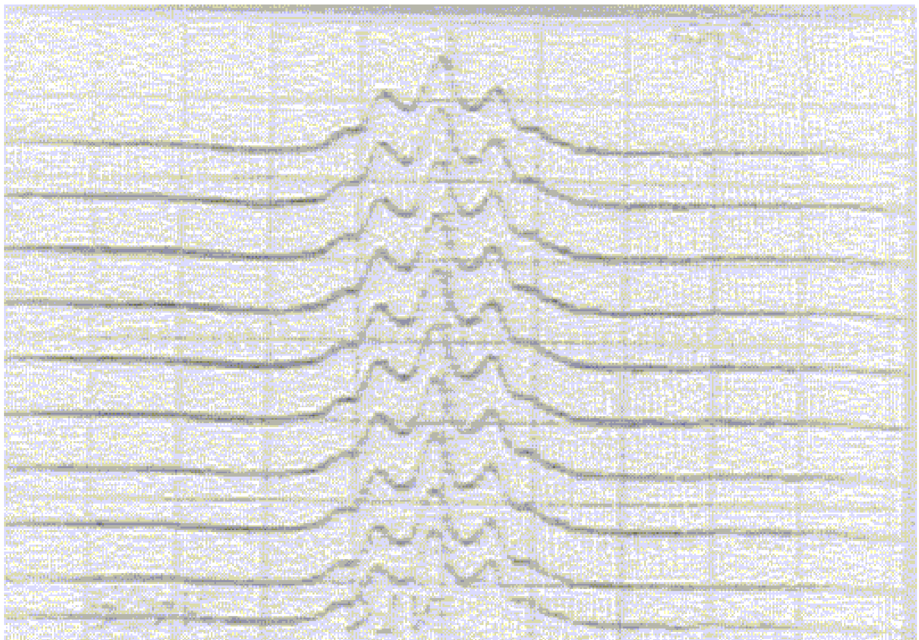


Transverse Instability

- Beam remnants point to coherent betatron mode with ***l=1***

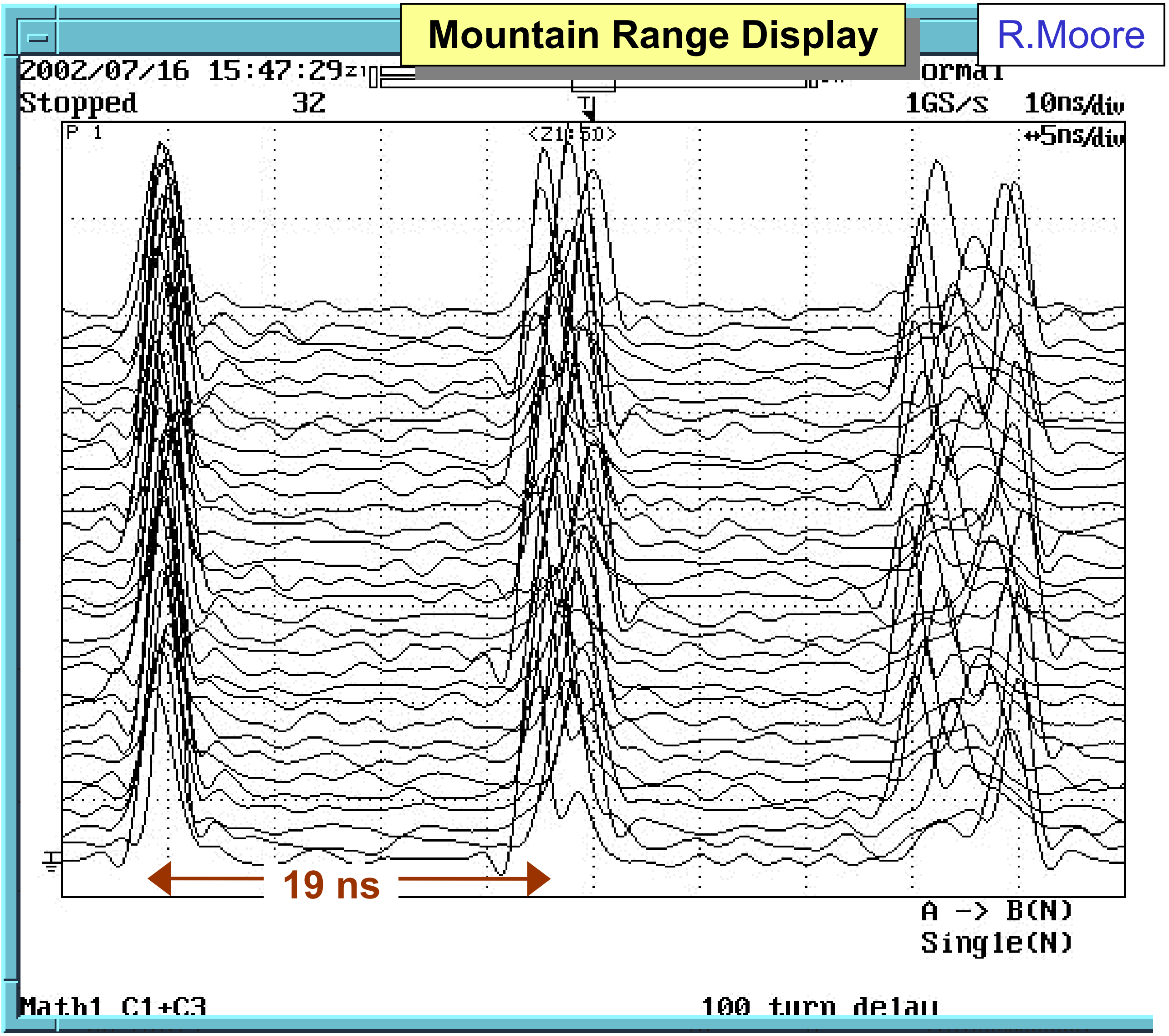
$$N_{ppb} = 2.65 \cdot 10^{11} (init.\ beam) \Rightarrow N_{ppb} = 0.7 \cdot 10^{11} (remain.\ beam)$$

P.Ivanov, A.Burov



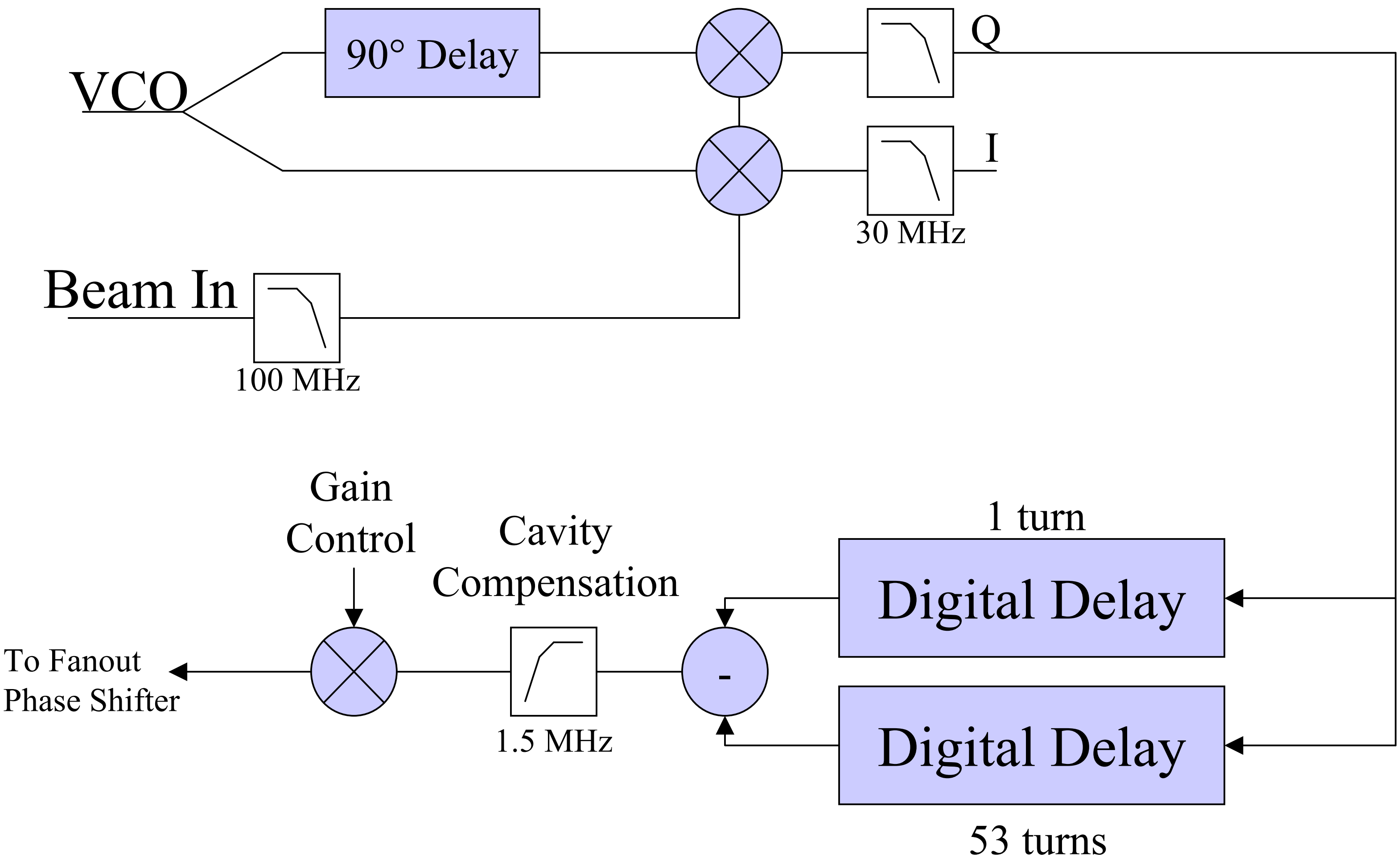
*Structure of the remaining beam longitudinal density points qualitatively at excitation of the coherent vertical oscillations with the dipole longitudinal configuration **l=1**.*

Longitudinal Impedance – "Dancing Bunches"

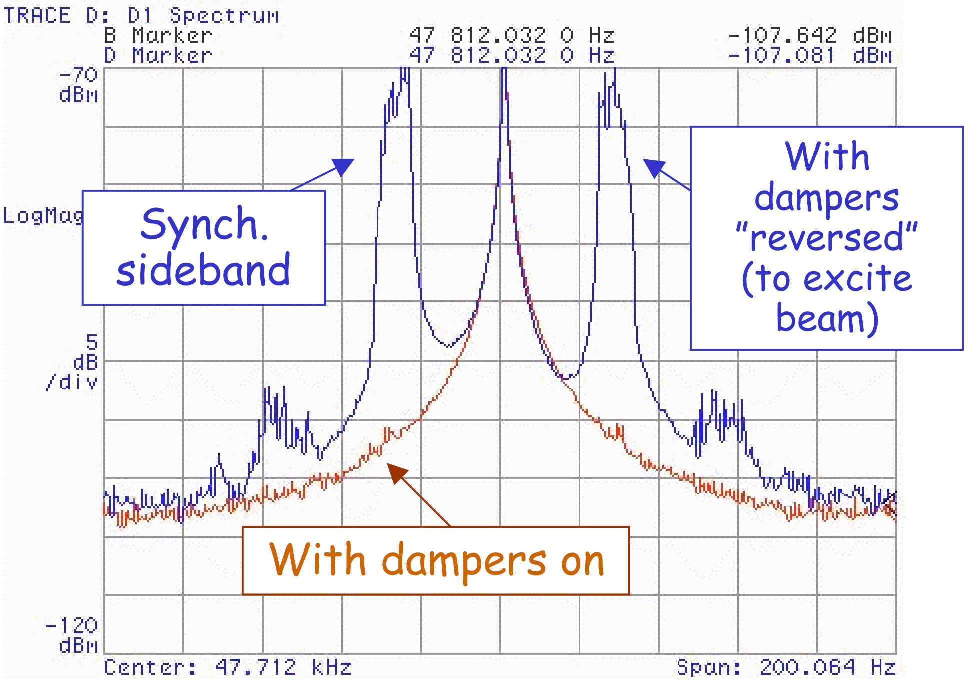


- Beam in 30 buckets
- 100 Tevatron turns (~2 ms) between traces
- Synch freq ~ 85 Hz
- Oscillation amplitude depends on bunch, changes slowly with time (minutes at 150 GeV, seconds at 980 GeV)
- Model needs inductive impedance Z/n ≈ 2 Ohm interplaying with cavity impedance
- Coalesced bunches have dancing bumps

TeV Longitudinal Damper Block



Tev Longitudinal Damper

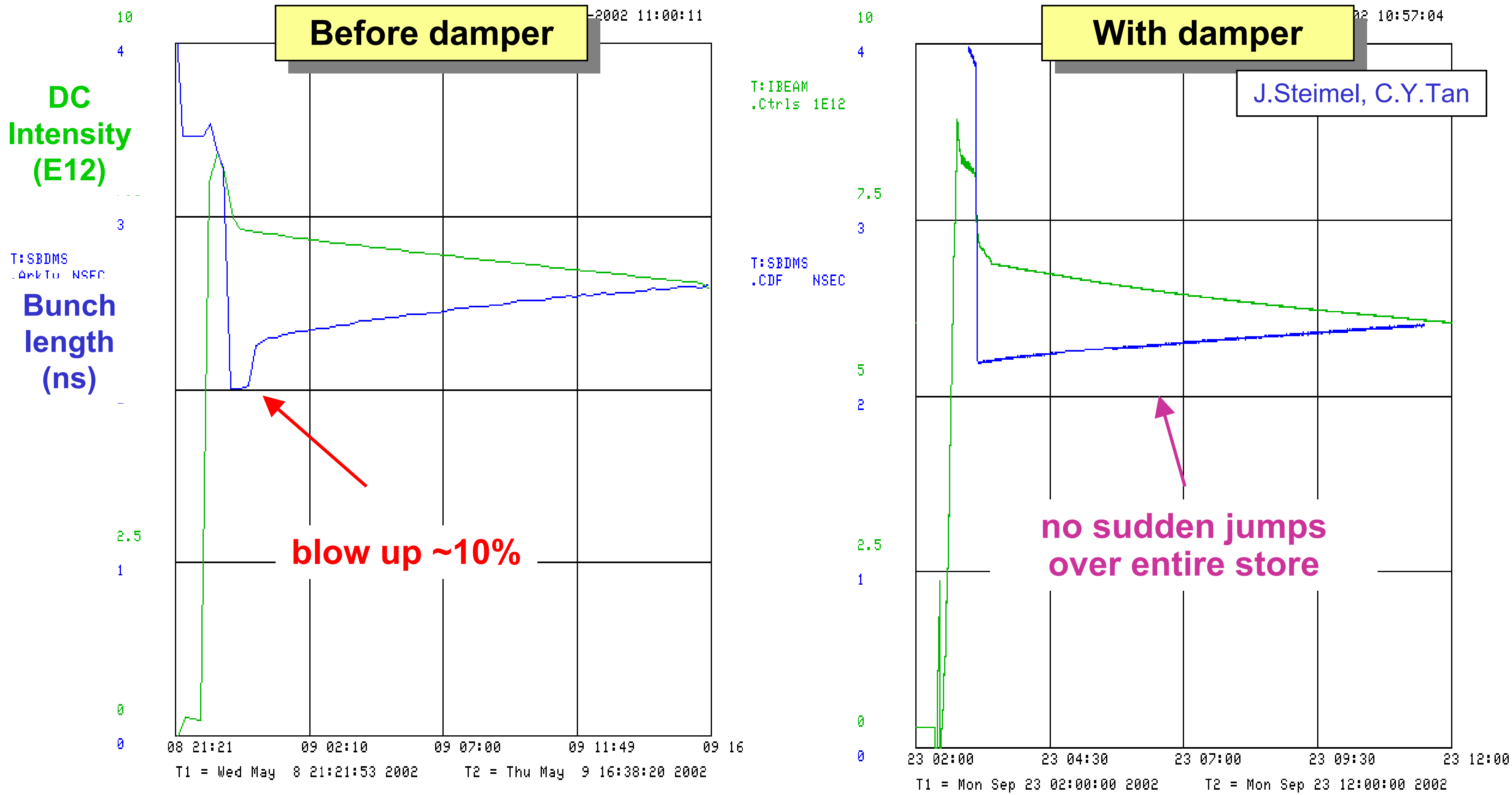


- Damper Hardware completed
- See excitation of synchrotron tune lines when damper is "reversed"
- Synchrotron sidebands damped when dampers are turned on.

Longitudinal dampers are on during a store.

No more sudden bunch length blowup is observed.

Bunch Length Blowup During Stores



- Intensity-dependent, leads to significant CDF background rise
- Usually only one or a few bunches would suffer
- Problem solved by <u>bunch-by-bunch longitudinal damper</u>

Diagnostics

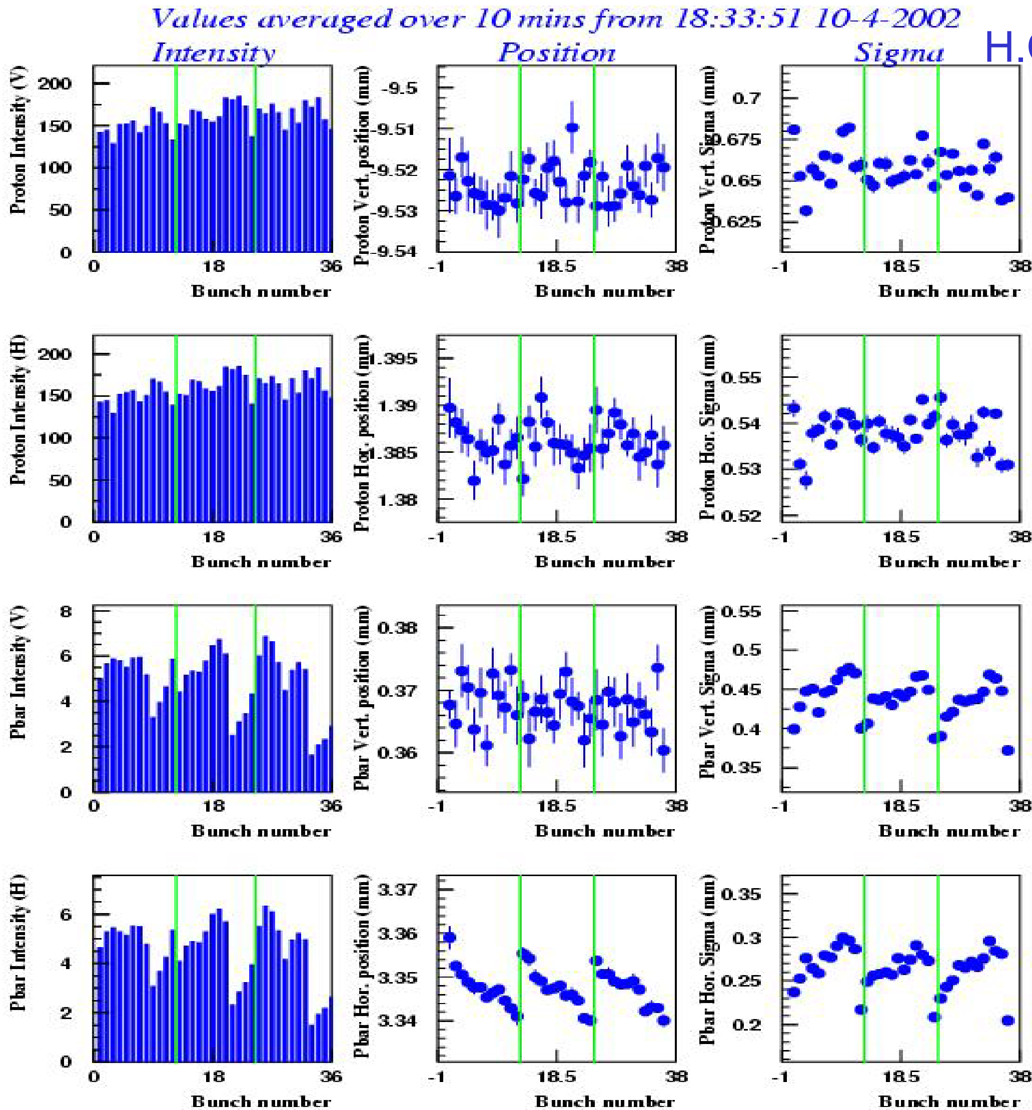
Slides Related to Diagnostics and Instrumentation

- Summary of Diagnostics and Status
- Progress with Synchrotron Light Monitor
- Emittance measurement comparison
  - Scrapers
  - Synchrotron Light Monitors
  - Flying Wires
- New Schottky Monitor
- Head-tail instability diagnositics
- BPMs

Diagnostics Progress/issues/needs

	Priority	Status
• BPMs	I	started
• Beam Line Tuner = BLT	I	good
• RF phase detector	I	good
• Flying Wires = FW	I	good
• SyncLite Monitor = SL	I	good-
• Single Bunch Display = SBD	I	good-
• Fast Bunch Integrator = FBI	I	good+
• Schottky Detector (21 MHz, + 1.5 GHz)	I	good
• Head-Tail Monitor	I	fair
• Tune-Meter, Tracker	I	fair
• On-line Chromaticity Measurement	I	started
• Digital Mountain Range	II	good-
• Fast Chromaticity Measurement	II	fair
• TEL Instrumentation	II	fair+
• RF Noise	II	good-
• BPM Upgrade	II	none
• Orbit Oscillations Monitor	III	fair
• Magnets motion	III	good

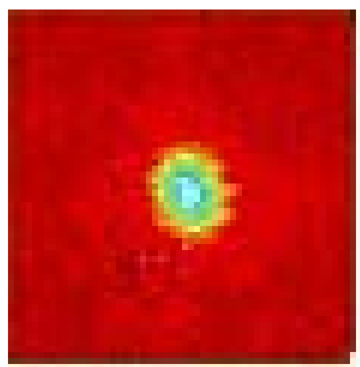
Diagnostics Progress: SyncLite Monitor



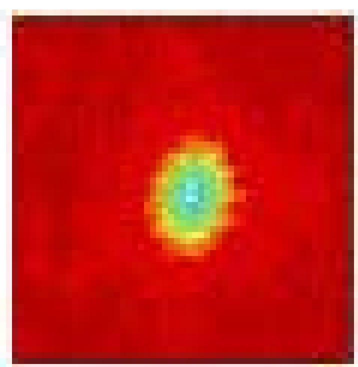
H.Cheung

- Works >800 GeV
- Significant progress since March'02
- Reports rms, mean, N, tilt bunch-by-bunch for both protons and pbars
- Invaluable instrument

Bunch #1

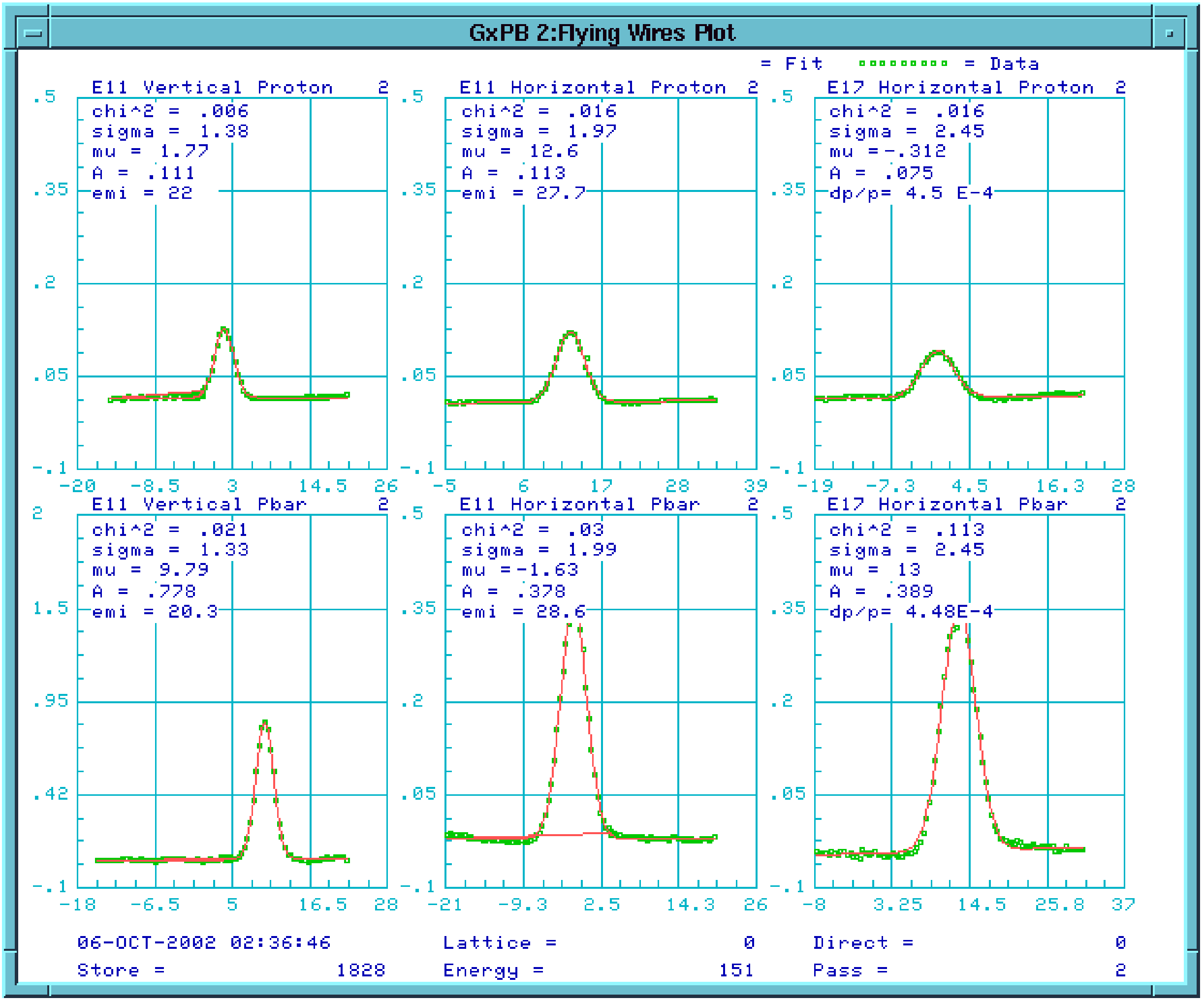


Bunch #8



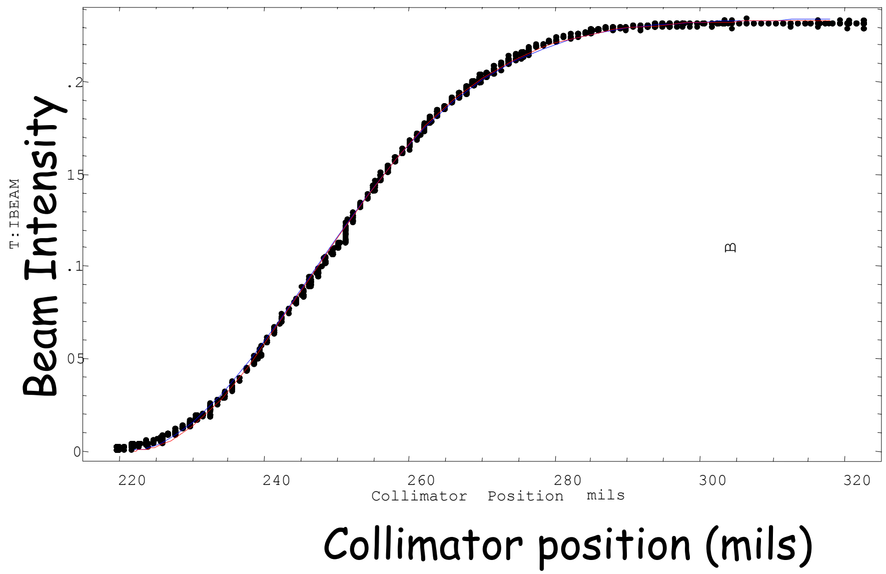
Diagnostics: Flying Wires

#1828, injection



- Proton channels tuned up in March
- Still some (15% ?) calibration needed
- Pbar channels data are subject of correction
- “Jumping” emittances
- (improper dP/P?)
- Recalibration of both p and pbar channels is due
- Need raw data

Tev Scraping Studies



Intensity versus collimator position assuming Gaussian beam (1D scraping):

$$N = N_0 \left(1 - e^{-\frac{(x - x_0)^2}{2\sigma^2}}\right)$$

Vertical prot emittance measurement
(95%, normalized)

Use scrapers to measure emittance. Then compare to FW and Sync. Lite

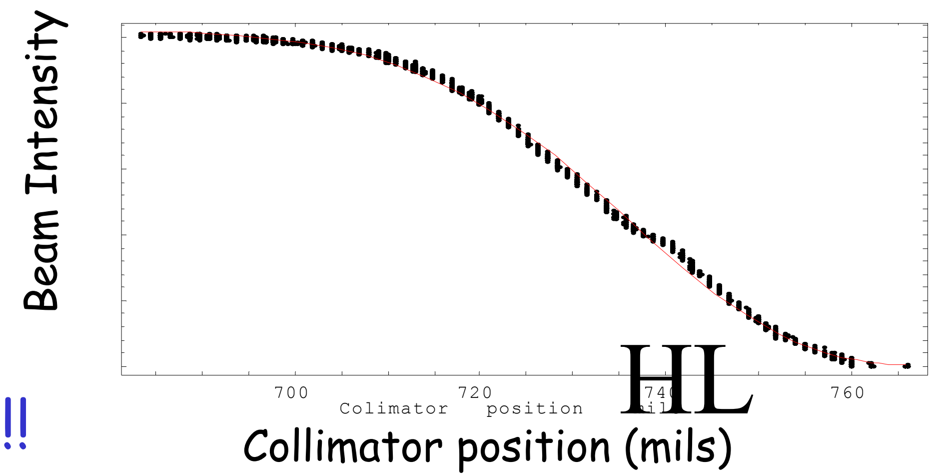
Scraping:	24-27 π
Flying Wire:	30 π
Sync. Lite:	34 π

Need to know β function at monitors!

Tev Scraping Studies

Horizontal proton

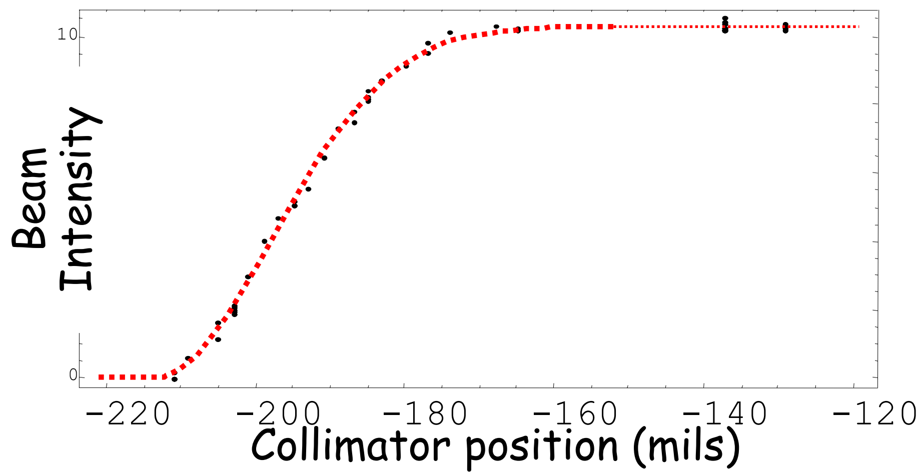
Scraping: 31-33 π
Flying Wire: 22-28 π
Sync. Lite: 34 π



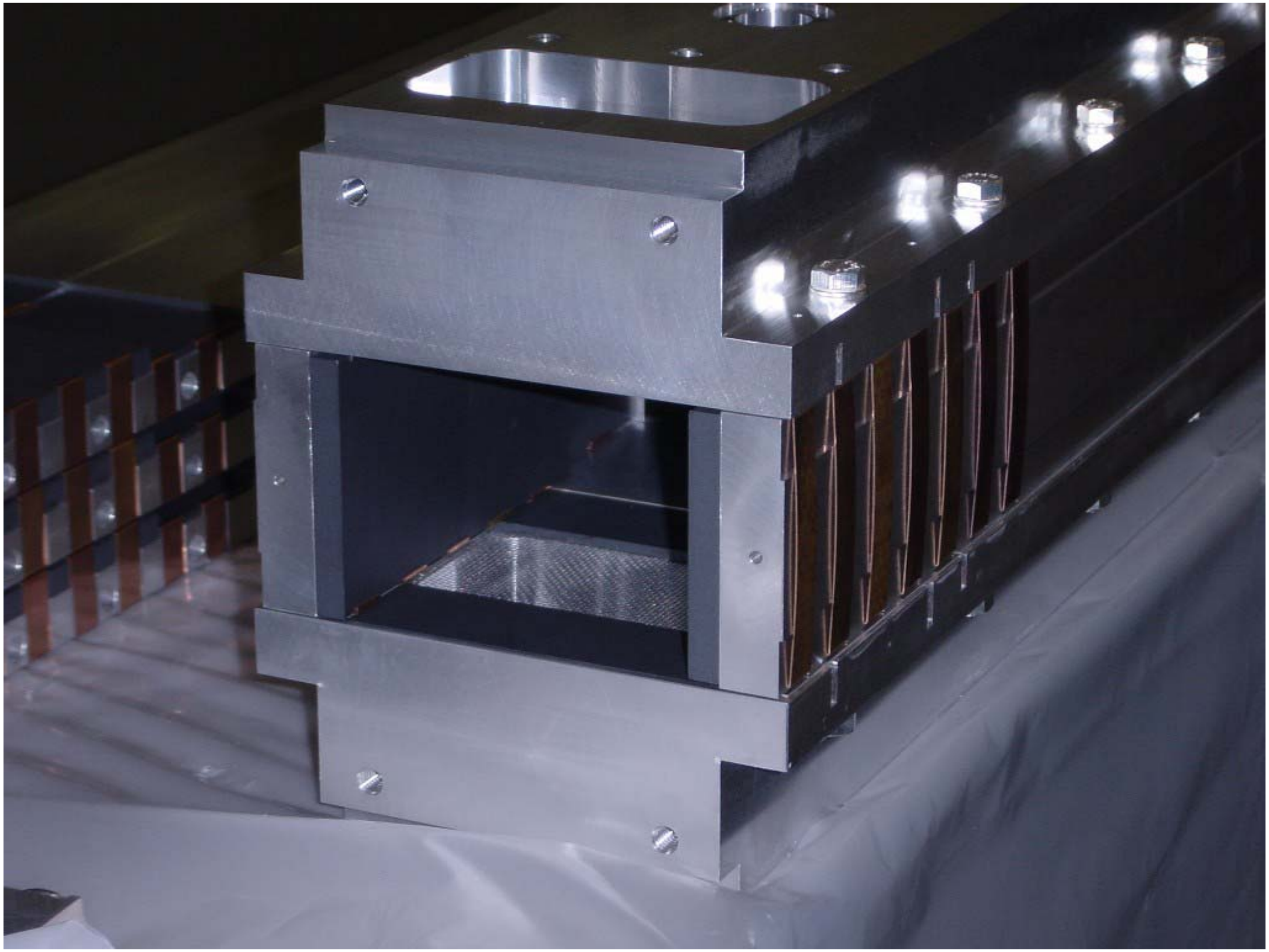
Dispersion is an issue !!!

Vertical pbar

Scraping: 20-24 π
Flying Wire: 42 π
Sync. Lite: 44 π



Schottky Monitor



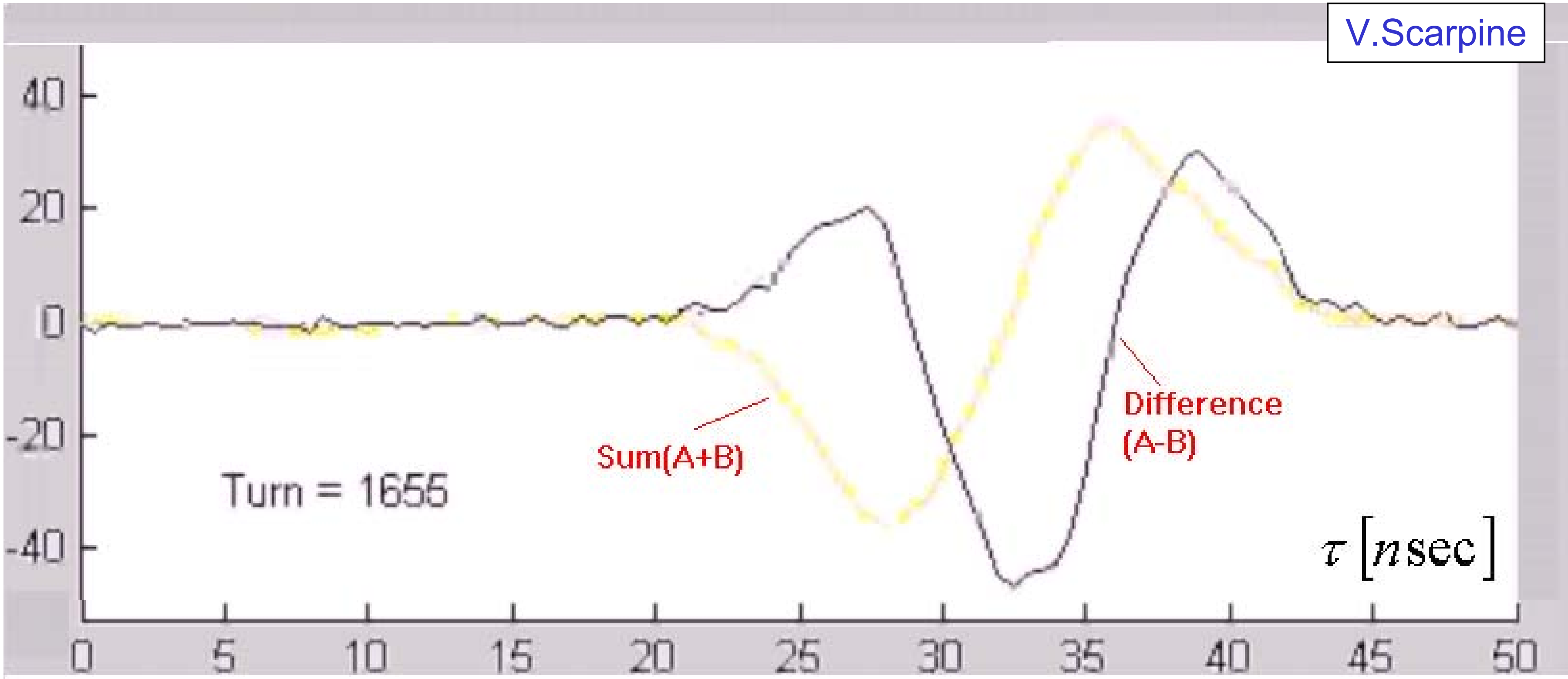
Schottky Monitor

- 1.75 GHz center frequency
- 100 MHz Bandwidth

- Used to
  - Measure emittance
  - Measure chromaticity non-destructively
  - Measure tunes of individual bunches

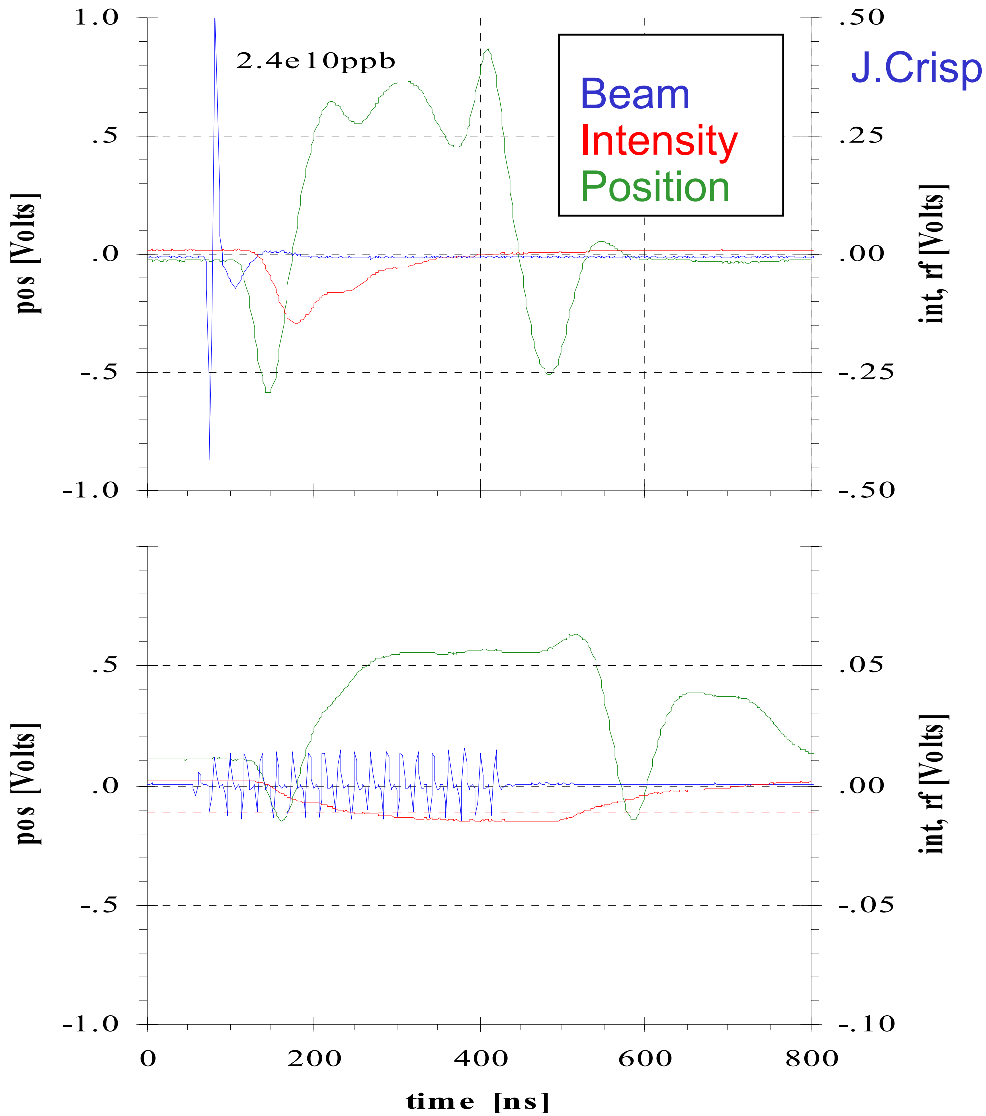
- Tank installed in January 2003 shutdown

Diagnostics: Head-tail Monitor



- BLT hard- and software to measure position within one bunch
- Goal of the HTM – monitor higher order head-tail modes
- To be used for chromaticity measurements (non?-destructively)

Diagnostics: BPMs



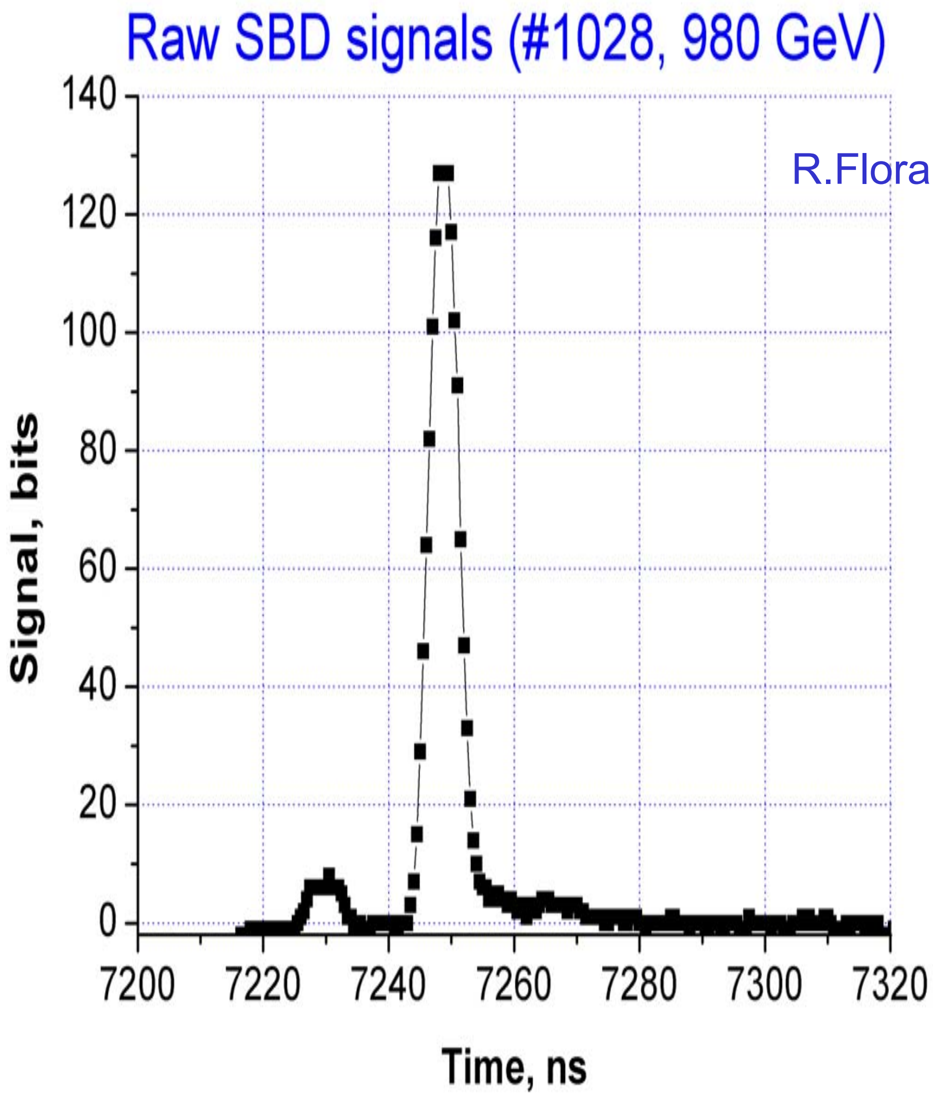
BPMs originally designed for 53 MHz beam structure

Work well now for uncoalesced beam

After some tuning BPMs worked in Run I with 6x6

Do not work with 36x36 because of bunch separation is smaller than filter ringing time

Diagnostics: SBD, FBI

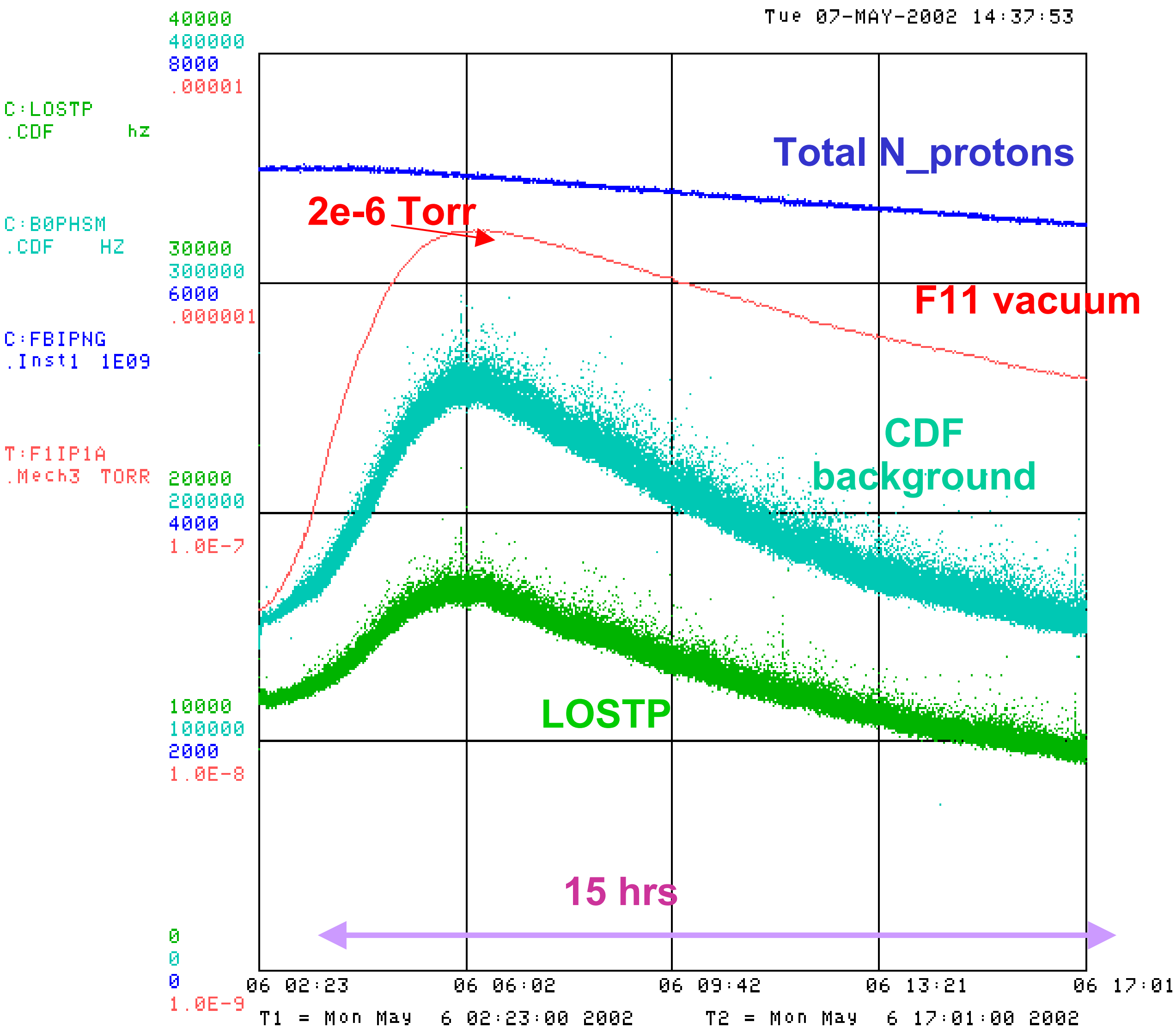


- Dispersion in long cable adds to σ_s, tails, satellites
- Raw data available On-Line
- Pbar channels affected by strong proton bunches
- Pbar bunch length not available in ACNET until final cogging (just fixed)
- FBI needs calibration (5%?) and proper offset subtraction especially in pbar channel
- FBI intensity depends on σ_s - need to be fixed
- Intensity from SBD

January 2003 Shutdown

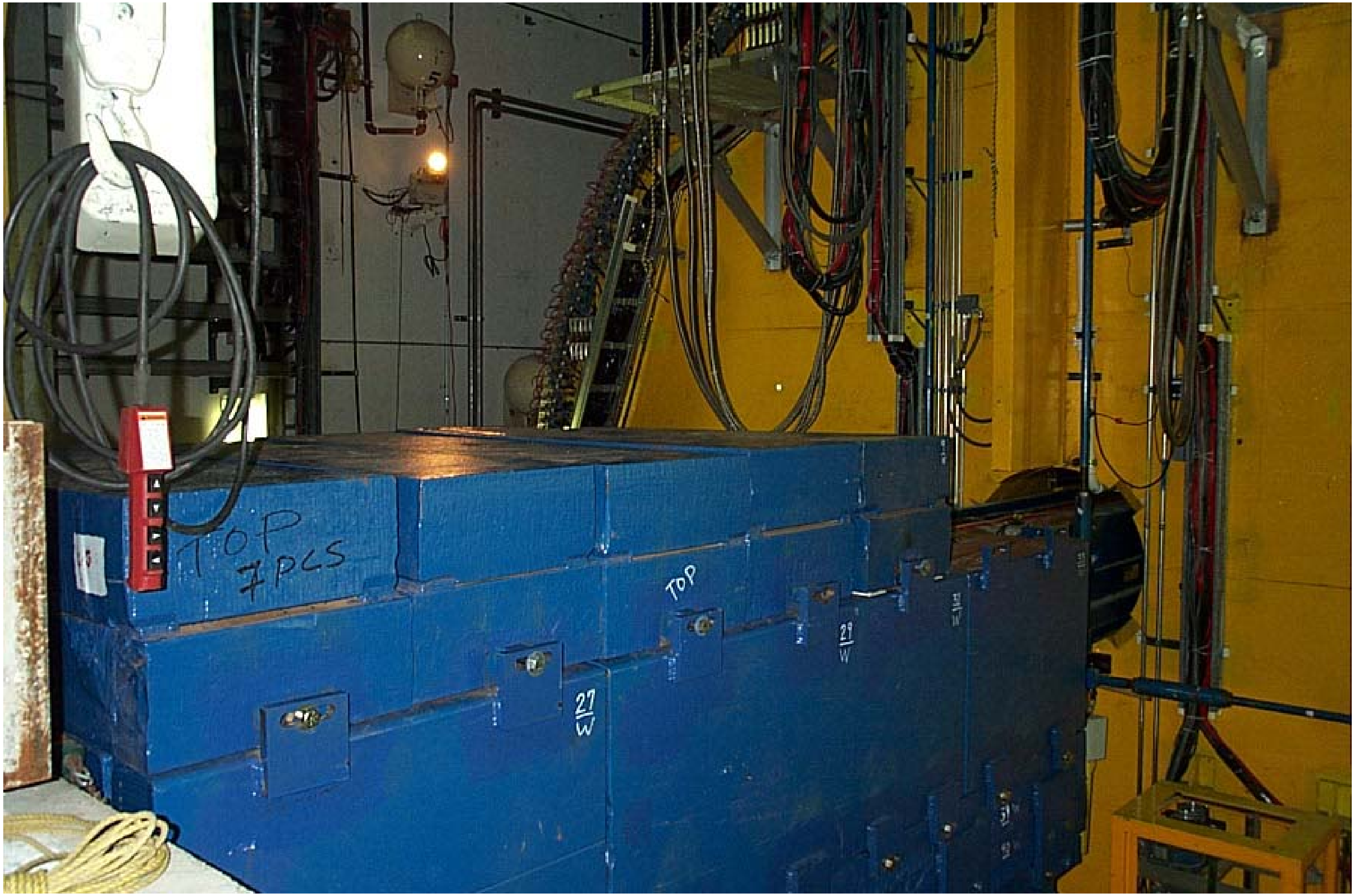
- C0 Lambertson Replacement
  - Increases aperture at C0
  - Leads to increased proton/antiproton helical orbit separation.
- Schottky monitor
  - Measure chromaticity non-destructively
  - Measure tunes of individual bunches
- CDF Shielding
  - Add steel around low beta quads.
  - Should reduce backgrounds in muon chambers by factor of 5.
- New TEL electron gun.
  - Gaussian shaped emittance of electron beam
- Alignment Work

Vacuum and Background



- for several months the CDF losses had bump few hrs into stores
- reason was out-gassing of ferrite absorber in RWM due to beam heating
- fixed in June'02
- that allowed to estimate average equivalent Tev vacuum pressure to be 1e-9 Torr (room T, N_2)

CDF Shielding



Performance: FY'03 Goals

Parameter	Current Performance	FY03 Goal	
Typical Luminosity	3.2e31	6.6e31	$cm^{-2}sec^{-1}$
Integrated Luminosity	6.0	12.0	pb^{-1}/week
Protons/bunch	170e9	240e9	
Antiprotons/bunch	22e9	31e9	
Proton emittance (95%, norm)	20	20	pmm-mr
Pbar emittance (95%, norm)	18	15	pmm-mr
Bunch length rms (prot, pbar)	0.6	0.54	meter

Most of the luminosity gain comes from more particles

- Higher N_p leads to beam-beam, instabilities, backgrounds
- Need to understand these physics issues
- Need time for studies

Tevatron Projects in FY'03

Priority	project	Leader	Date	N_P	N_A	emm
1	**Transverse dampers**	*Steimel*	Nov'02	■		
1	**Pbar emittance at injection: BLT,A1 line, inj.damper**	*Scarpine* *Lebedev* *Steimel*	Nov'02 Dec'02 Feb'03	▪	■ ■	■ ■ ■
1	**C0 Lambertson replacement**	*Garbincius*	Feb'03	▪	■	
1	**Tev Lattice (A0)**	*Martens*	Feb'03		■	
1	**Daily operations**	*TeV coord*	daily	▪	■	■
1	**Operational orbit smoothing**	*Martens*	Dec'02	■	■	
1	**Beam-beam studies and calculations**	*Sen*	Sep'03	▪	■	■

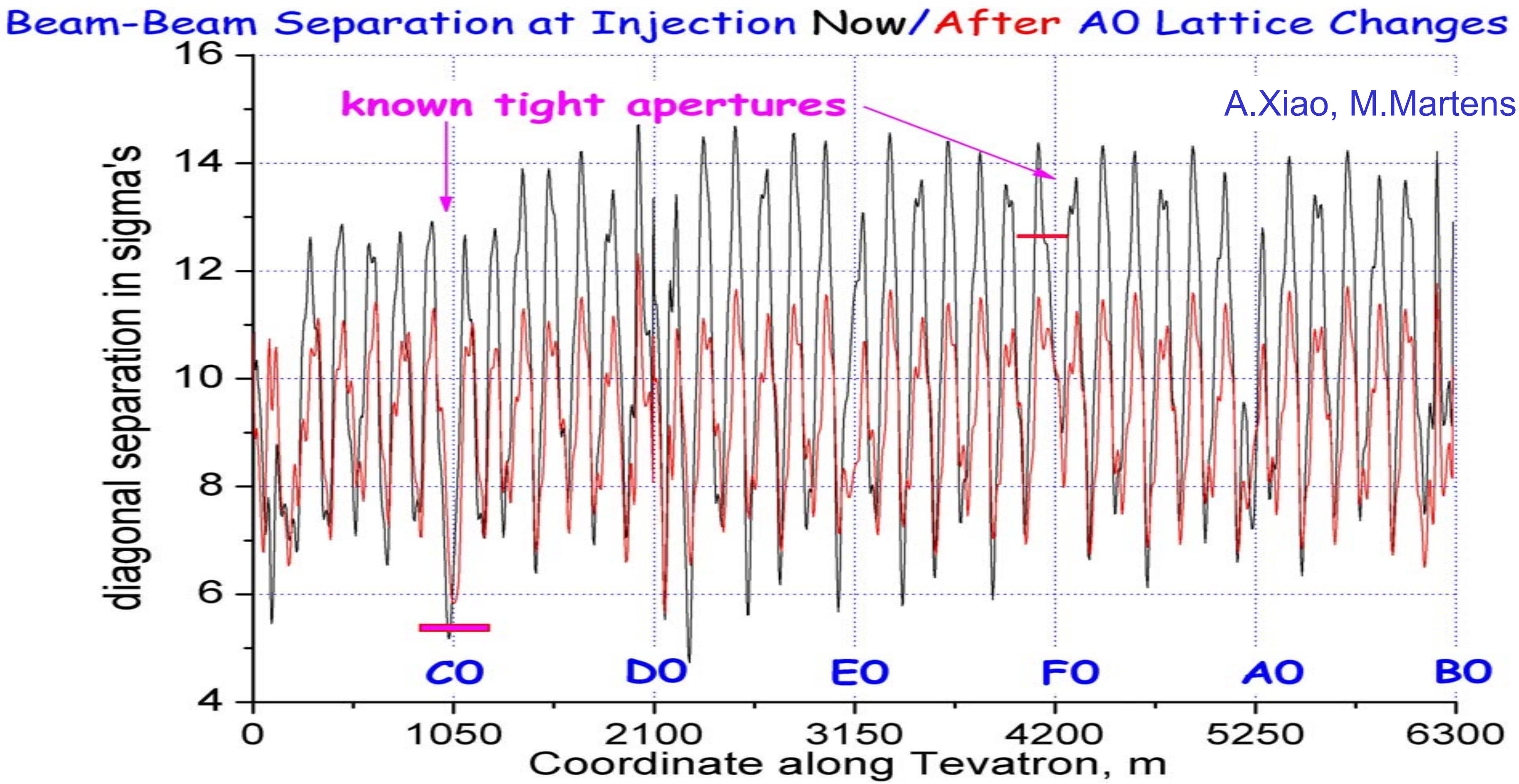
Tevatron Projects in FY'03 (Cont'd)

Priority						
2	**Instability studies**	*Ivanov*	Dec'02	■	■	
2	**150 GeV tunecoupling drift compns; b2 unwind**	*Martens*	Oct'02		■	
2	**TEL**	*Shiltsev*	Feb'03	■	■	
2	**Schottky detector at E17**	*Pasquinelli*	Feb'03		■	
2	**Tevatron alignment**	*Stefansky*	Mar'03		■	
2	**Longitudinal dampers**	*Steimel*	Apr'03	■		
3	**Tevatron vacuum**	*Hanna*	Feb'03	■	■	
3	**Losses/collimators**	*Moore*	Feb'03	■		
3	**DC Beam/RF noise**	*Lebedev*	Apr'03	■		
3	**SBD/FBI/FW (BPMs)**	*Pordes*	Dec'02	■	■	■
3	**SynchLite**	*Cheung*	Dec'02	■	■	■
3	**Chromaticity measurement**	*Still*	Dec'02		■	
3	**Orbit motion spectrometer**	*Zhang*	Dec'02	■		■
3	**Pbar tunemeter, feedback**	*Tan*	Mar'03		■	

FY'03 Shutdown(s)

- Projects for FY'03:
  - Alignment work
  - A0 lattice modification (?)
  - Vacuum improvement (incl., warm two houses)
  - Install new collimator at A48 (?)

Lattice Modification at Sector A0



- Proposed modification promises 16% larger min separation at injection (5.6 vs 4.7 ♦)
- Benefits still to be quantified given that C0 aperture will be opened for sure

Physics Progress

- **Beam-beam issues**
  - N_p effect (pbar only, efficiencies vs N_p)
  - Emittance+aperture effects (C0 + F0 + A0, ♦ vs Aperture)
  - Tune, κ, C_v,h, orbit effects (variations, smoothing, compensation)
  - Lifetime/other effects in collisions (breakdown, b-to-b orbits, tilts, sigmas)
  - Beam-beam effects for protons (at LB)
  - IPs (luminous regions, separator scans, coupling)
  - TEL (better lifetime, Gaussian gun)
- **Instabilities/blowups**
  - Coherent transverse (coherent, b-to-b, HOMs, C_v,h, dampers, octupoles)
  - Coherent longitudinal (♦$_s$ blow-up, b-to-b, damper, dancing bunches)
  - Incoherent transverse (150 loss loss vs C_v,h, d♦$_s$ /dt, emittance growth)
  - Incoherent longitudinal (d♦$_s$ /dt vs N_p)
  - Orbit drifts (tides+Temperature +drifts)
- **Losses/background**
  - Vacuum (F11, IPs)
  - DC beam (DC loss rate in store)
  - Collimators (new at A48)

Summary on Tev Luminosity in '03

- Aggressive pursuit of pbar intensity at low-beta, moderate on protons, about same emittances
- projects and expectations — gain in $\mathcal{L}$
  - Transverse dampers — ~15-20%
  - Fix A1/P1 inj lines — ~10-20%
  - Open C0 aperture — ~10%
  - Better focus at IPs — ~0-10%
    - smaller β*; local decoupling; shorter bunch length
  - Beam-beam tuneup — >5% ?
    - Tunes/coupling; TEL; smaller dp/p; shave in MI; RF noise; vacuum
  - A0 lattice modification — 0-5% ?
  - Diagnostics improvement — + in integr. $\mathcal{L}$

Summary

- Significant luminosity improvement
  - 5 times since October'01
  - 3 times since March'02
- Complex running well lately
  - Now consistently above Run I peak luminosities
- Delivered 76 pb^{-1} to each experiment in FY'03
- Made significant progress on many issues.

Summary

- Need to continue progress on
  - Beam-beam
  - Instabilities
  - Diagnostics
- Looking forward to delivering 0.2-0.32 fb^{-1} in FY'03
  - increase peak luminosity to (5-7)e31
    - about +12% (stretched to 24%) more protons to collisions
    - about +35% (stretched to 60%) more antiprotons to collisions
    - about the same emittances